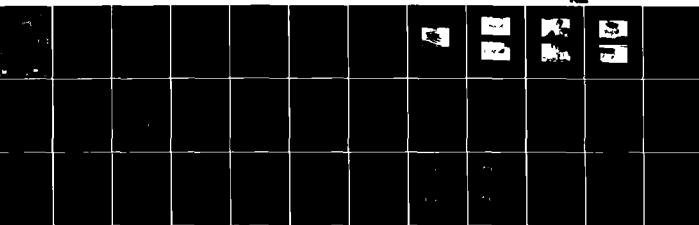


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EVALUATION OF ICE DEFLECTORS ON THE USCG ICEBREAKER POLAR STAR.(U)
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EVALUATION OF ICE DEFLECTORS ON
THE USCG ICEBREAKER, POLAR STAR

George P. Vance

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UNITED STATES ARMY
CORPS OF ENGINEERS
COLD REGIONS RESEARCH AND ENGINEERING LABORATORY

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concept appeared to be the bilge keels. Open water power tests and structural analysis must now be carried out to determine the overall feasibility of these concepts.

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PREFACE

This report was prepared by Dr. George P. Vance, Research Engineer, of the Ice Engineering Research Branch, Experimental Engineering Division, U.S. Army Cold Regions Research and Engineering Laboratory. Funding for this research was provided by the U.S. Coast Guard under Interagency Order Z70099-9-91769-9B.

The manuscript of this report was technically reviewed by Guenther Frankenstein and Thomas Tantillo of CRREL.

The tests were the first ship model tests conducted in the new Ice Engineering Facility Test Basin. Appreciation is extended to Ronald Farr and the members of the Ice Engineering Research Branch for assistance in conducting these tests. Special appreciation is also due to Thomas Marlur of the CRREL Photo Service Section and D.B. Larr of the USAE-WES Photo Service Section for their dedicated assistance in obtaining the underwater high-speed movies of the tests. Particular thanks and appreciation is extended to R.W. Gulick for his support and assistance during the tests and his significant contribution to the tests and the analysis of the results.

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EVALUATION OF ICE DEFLECTORS ON THE
USCG ICEBREAKER POLAR STARR (WAGB-10)

by

George P. Vance

INTRODUCTION

The U.S. Coast Guard's newest and most powerful icebreaker, the Polar Star (WAGB-10), has had considerable problems with ice ingested into the propeller slip stream. The Polar Star has a unique triple screw controllable pitch propeller system and the ice that is ingested into the slip stream has caused damage to the pitch control mechanisms. In order to eliminate or at least mitigate this problem, the Coast Guard was interested in evaluating devices that would keep the ice out of the propeller slip stream.

After lengthy discussions with CRREL personnel, several candidate devices were selected and a model test program to evaluate these devices was established. The tests were carried out in the refrigerated test basin of the Ice Engineering Facility.

BACKGROUND

The decision to use the CRREL test basin for the model tests of the Polar Star ice deflectors was based upon the following:

1. The test would be mainly qualitative and depend largely on visual observations.
2. Movies were desired of the side and bottom of the model during ice breaking.
3. A large model, i.e. small scale ratio, was desired.
4. The tests were to be conducted in real ice in a refrigerated facility.

The new CRREL facility could meet all these objectives.

A 1 to 19.1 wooden model of the Polar Star was built by the David Taylor Navy Ship Research and Development Center and outfitted with three properly scaled stock three-bladed propellers, three 1.5-hp drive motors and shafting, three single-phase motor controllers, three magnetic RPM pickups and a frequency to voltage converter for the RPM pickups.

The model was shipped to CRREL and the tests were conducted from 13 April to 7 May 1979. The model was 21 ft long, 4.5 ft wide and 2 ft deep. It weighed 1200 lb with no ballast and required over 2000 lb of lead ballast to float at the correct draft.

DESCRIPTION OF TESTS AND EQUIPMENT

Tests were run on each type of deflection device shown in Figures 1-4, and on the bare hull. Each device was evaluated at two ice thicknesses and two speeds. The bilge keels were evaluated at two widths: 40 in. at full scale and 10 in. at full scale.

The RPM of each shaft and the speed of the model were recorded on a Gould recorder, a Honeywell high-sensitivity recorder and on magnetic tape on a Hewlett-Packard tape deck. The speed was measured using a Kustom Signal HR-4 radar system. The Doppler radar was only capable of detecting speeds down to about 1 ft/sec.

In addition to the RPM and vessel speed measurements, high-speed movies were taken from directly beneath the model and from the side of the model.

The model was free-running and controlled with an umbilical cord. A saline ice sheet of specified thickness was prepared and the RPM of the propellers was preset before each run. The model then proceeded down the tank and over the movie cameras. Each run used one half of the ice sheet. After each run, the RPM was reset to another level and the camera and control equipment were shifted so that a second run could be undertaken.

The movies and oscillograph records were immediately turned over to the Coast Guard for their use.

TEST RUNS

In all, 25 test runs were conducted. The results of these runs are presented in this report in the form of the RPM recordings for each shaft and speed recordings for each run (App. A).

Due to the extreme environment, difficulties with the sensors occurred during some runs and data signals were partially or totally lost. Any difficulties encountered during a run are explained in the preface to the run.

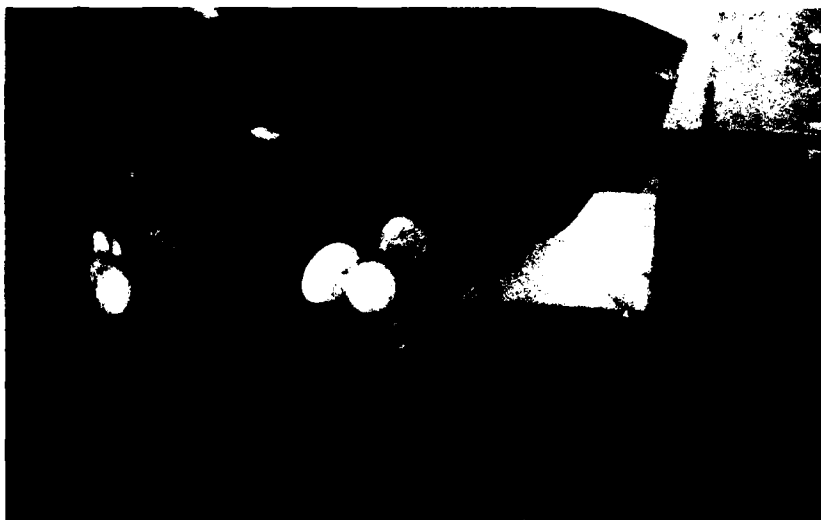
The speed records may appear to be erratic; however, the pitching and rolling motion of the model caused erratic signal reflection from the reflector installed on the model.



Figure 1. Ice deflectors before installation.

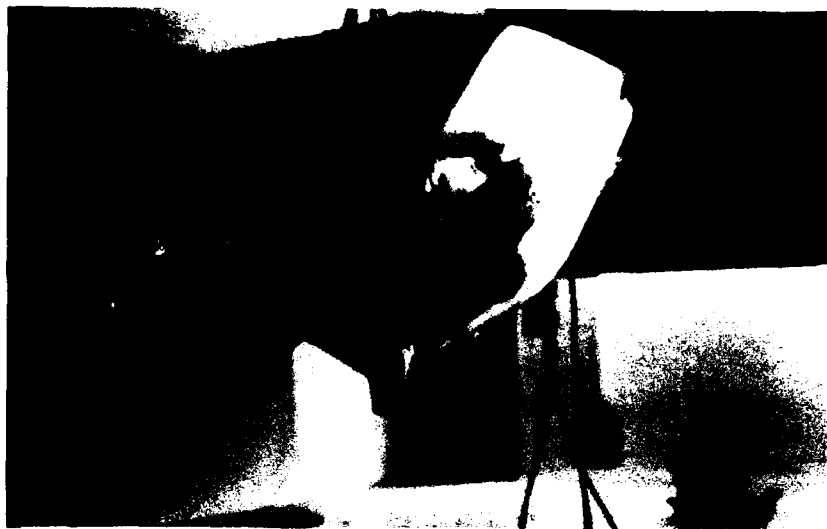


a. Stern view



b. Starboard quarter view

Figure 2. Bossing fins.

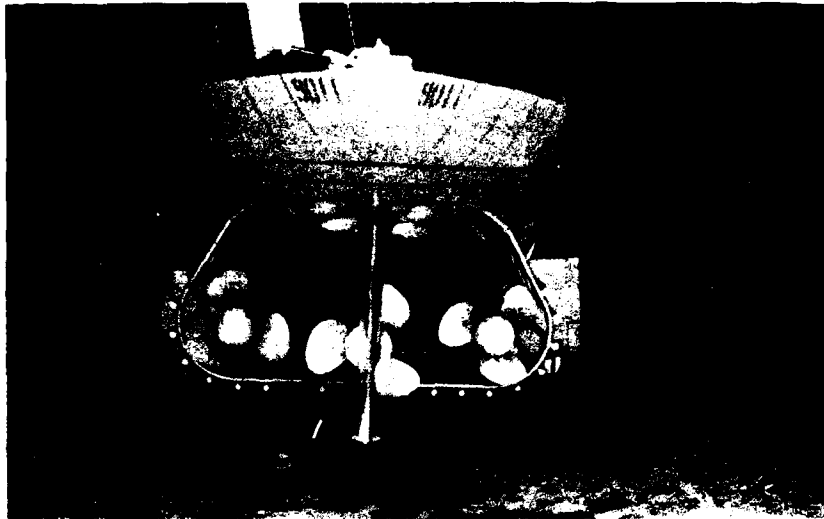


a. Bow view



b. Starboard quarter view

Figure 3. Large bilge keels.



a. Stern view



b. Starboard quarter view

Figure 4. Bird cages.

RUN 0-1

Run 0-1 was conducted on 13 April 1979. In actuality it was a calibration run to check the system's performance. No movies were taken during this run. The ice thickness was relatively thin at 0.5 in. model scale (ms) or 9.55 in. full scale (fs). Even though there were no deflector devices, there were relatively few impacts with the propellers, as can be seen from the RPM records. Model speed was 3.4 ft/sec (8.8 knots fs).

RUN 0-2

Run 0-2 was conducted under similar conditions as 0-1; however, the speed was reduced to 0.9 ft/sec (2.4 knots fs). There were virtually no impacts with the propeller.

RUN 1-1

There were no deflection devices installed in this run. The ice thickness was about 0.55 in. (10 in. fs) and the model speed was 3.2 ft/sec. (8.2 knots fs). One can detect several impacts on the port shaft.

RUN 1-2

Conditions were similar to run 1-1 with a speed of 1 ft/sec (2.5 knots fs). Again there are impacts noted on the port propeller.

RUN 2-1

No deflectors were installed on this run; however, the ice thickness (1.14 in.) was greater than that from run 1-1 and the model speed (2.4 ft/sec) was slightly faster than for 1-1 and 1-2. Considerable impacts with all three propellers can be detected. The port shaft was stopped during part of the run due to a malfunction of the motor controller.

RUN 2-2

Conditions were similar to run 2-1; however, the model speed was much slower (1.14 ft/sec) and fewer impacts can be detected.

RUN 3-1

The bossing fins were installed during the run and a considerable number of impacts can be noted. The radar recorder malfunctioned during this run; however, visual observations were made on the radar unit itself. The average speed was 3 ft/sec (7.7 knots fs) and the ice thickness was 1.02 in. (20.4 in. fs).

RUN 3-2

This run was almost identical to 3-1 with the radar in operation.

RUN 4-1

In this run the rotation of the outboard propellers was reversed; i.e. the port propeller turned clockwise and the starboard propeller turned counterclockwise viewed from astern. Considerable impacts can be detected. The model speed was 4.6 ft/sec and the ice was 1.02 in. thick.

RUN 4-2

The model speed in the run was reduced to 2.3 ft/sec; however, considerable impacts can be detected. Ice thickness was the same as in run 4-1.

RUN 5-1

The bird cage deflectors were installed in this run. Impacts can be detected on all shafts; however, the port shaft's erratic behavior is due to the malfunction of the motor controller. The model speed was 2.5 ft/sec and the ice was 2 in. thick.

RUN 5-2

This run was conducted under conditions similar to those of run 5-1 except that a much slower model speed (1.7 ft/sec) was used. Again the port controller malfunctioned. Most impacts were encountered by the center shaft. The radar recorder also malfunctioned in this run.

RUN 6-1

The large bilge keels were in place for these tests. Relatively few impacts can be detected in this run. The model speed was 2 ft/sec and the ice was 1.5 in. thick.

RUN 6-2

The same conditions existed in this run as in run 6-1; however, the model speed was reduced to 1.5 ft/sec. Almost no impacts can be detected.

RUN 7-1

The large bilge keels were installed and the ice thickness was reduced (compared to run 6) to 1.3 in. In this run the model speed was

2.73 ft/sec. The RPM pickup on the center shaft malfunctioned at the middle of the first run and no signals could be obtained for the rest of the day. The port shaft RPM controller changed the RPM of the shaft in the middle of the run. Relatively few impacts could be detected.

RUN 7-2

The same condition as in run 7-1 existed; however, the model speed was much lower (1 ft/sec). The center RPM pickup was still inoperative, and relatively few impacts were experienced.

RUN 8-1

This run was conducted in 1.2 in. of ice (2 ft at fs) with bird cages at 1.36 ft/sec (3.5 knots at fs). The centerline RPM indicator malfunctioned.

RUN 8-2

This run was conducted at a faster speed (3.0 ft/sec) than run 8-1. The centerline RPM indicator was functioning. There appeared to be fewer impacts during the run.

RUN 9-1

This run was with a bare hull and very thick ice, i.e. 61.2 in. full scale (3.06 in. ms), and a considerable number of impacts occurred. Model speed was 3.6 ft/sec (9.4 knots fs).

RUN 9-2

This run was similar to run 9-1; however, the model speed was reduced to 1.6 ft/sec. There still appeared to be a considerable number of impacts. The centerline indicator malfunctioned.

RUN 10-1

This run was conducted with bossing fins in place at a model speed of 1.8 ft/sec (4.7 knots fs) and an ice thickness of 1.8 in. (37.2 in. fs). Although many impacts occurred, there were not as many as with a bare hull.

RUN 10-2

This run was similar to 10-1 with the speed of the model reduced to 1.36 ft/sec. The fins appear to have had very little effect on impact and, in fact, increased the number of impacts on the centerline propeller.

RUN 11-1

The model was fitted with bilge keels (10 in. fs). They appeared to diminish the frequency of impacts; however, they did not appear to be as effective as the larger bilge keels (40 in. fs). The centerline RPM pickup malfunctioned. The model speed was 1.82 ft/sec (4.7 knots fs) and the ice thickness was 1.57 in. (30.1 in. fs).

RUN 11-2

This run is similar to run 11-1, but at a lower model speed (1.63 ft/sec). The centerline RPM indicator was in operation.

RUN 12-1

This run was a demonstration run for Coast Guard representatives. No protection devices were employed and a significant number of impacts could be observed on all shafts. The model speed was 1.63 ft/sec (4.23 knots fs) and the ice thickness was 2.28 in. (43.6 in. fs).

CONCLUSIONS AND RECOMMENDATIONS

The tests conducted and described in this report were very successful and indicated the feasibility of an ice deflecting device for the Polar Star. From initial analysis of the data presented in this report and the oscillograph records and the high-speed photographs, it appears that bilge keels are the most successful deflectors and that bird cages are adequate but would need further design improvement. The bossing fins did not appear to be effective, and under certain circumstances evidenced more ice impacts than the bare hull. Table 1 is a summary of the estimated impacts for each run.

It is recommended that the project be pursued further by evaluating the candidate devices in open water to determine their effect on the open water resistance of the vessel with the devices in place. The structural feasibility of the devices should also be investigated to ensure that the devices could withstand the stresses imposed by the ice sheet as it impacted on the deflector.

In order to avoid the malfunctions experienced in the series of tests, it is recommended that future tests be conducted after the self-propelled towing carriage is installed at CRREL. The carriage's instrumentation cab will provide a protected environment for the motor controllers and some of the other instrumentation, thereby providing more reliability during the testing.

Figures 5 and 6 show a comparison of a test with and without a deflector device. A significant difference in the number and magnitude of the impacts can be seen between the model with and without the small bilge keels under such ice and velocity conditions.

Table 1. Ice deflector data

	Full-scale ice thick. (in.)		RPM	Impacts			Total impacts
				P	£	S	
Bare hull	1-1	10	200				
	1-2		400				
	2-2	23	200	0	0	1	1
	2-1		400	15	8	45	68
	9-1	61	550	102	121	122	345
	9-2		600	110	-	106	£ +216
Reverse rotation	4-2	20	400	33	17	14	64
	4-1		500	27	23	16	66
Fins	3-1	20	400	39	15	40	94
	3-2		500	59	30	57	146
	10-1	36	500	45	35	45	125
	10-2		550	45	33	25	103
Bird cage	8-1	24	300	13	-	2	£ + 15
	8-2		400	28	27	10	65
	5-1	40	500	-	20	14	P + 34
	5-2		400	-	22	22	P + 44
Large bilge keel	7-2	27	400	12	0	-	S + 12
	7-1		500	3	8	6	17
	6-1	36	400	4	23	15	42
	6-2		500	0	14	18	32
Small bilge keel	11-1	33	400	10	3	12	25
	11-2		500	1	5	9	15

Summary	Ice thickness	
	20-27 in.	33-40 in.
Bare hull	68	-
Reverse rot.	64/66	-
Fins	94/146	125/103
Bird cage	65	66/50
Large bilge keel	24/17	42/32
Small bilge keel	-	25/15

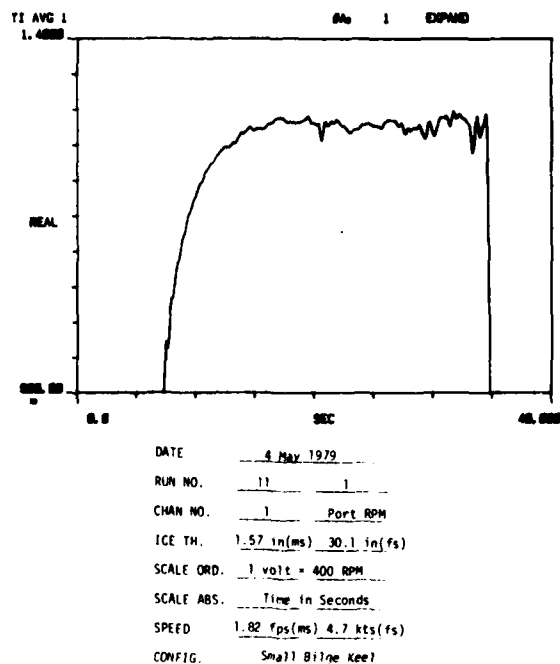


Figure 5. Starboard shaft RPM with small bilge keels.

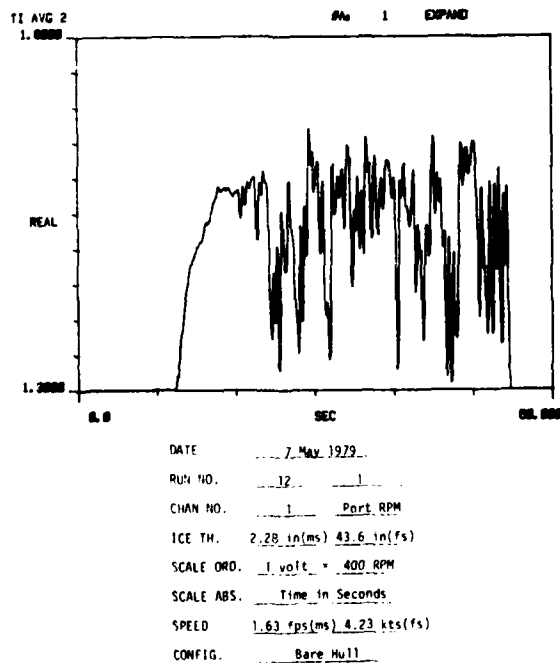
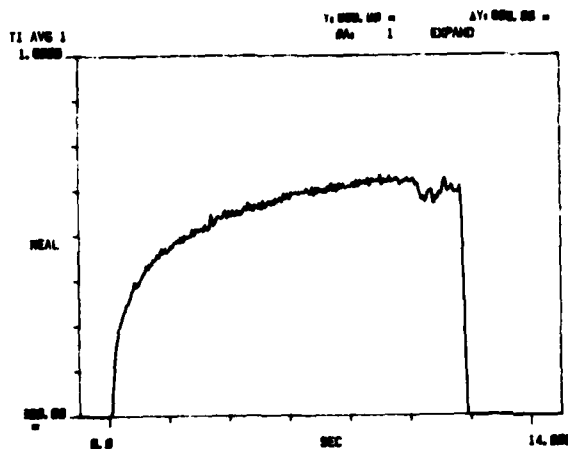
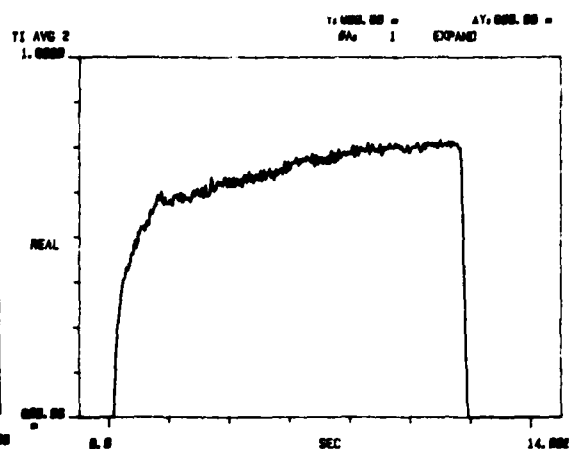


Figure 6. Starboard shaft RPM without protection devices.

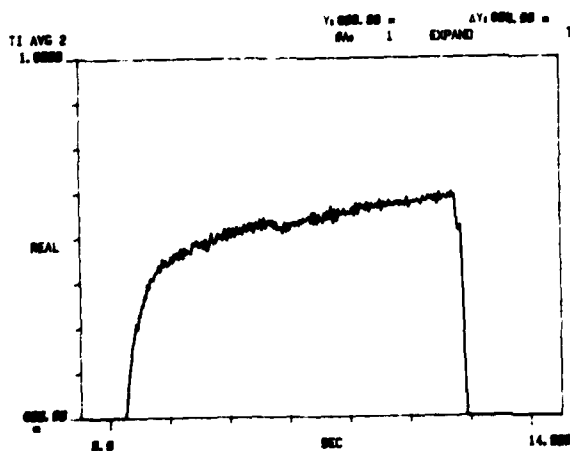
APPENDIX A: TEST RUN PLOTS



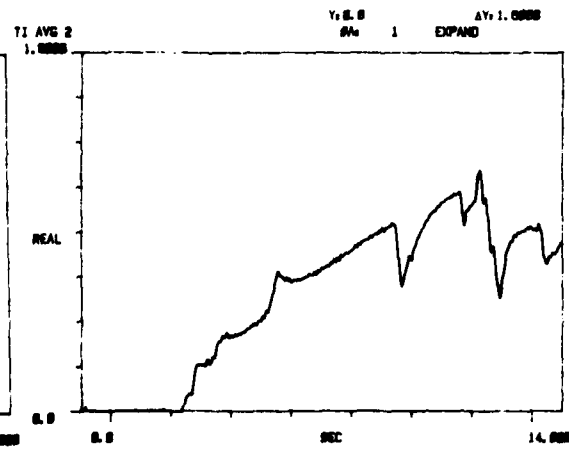
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 SCALE ABS. Time in Seconds
 SPEED 3.4 fps(ms) 8.8 kts(fs)
 CONFIG. Bare Hull



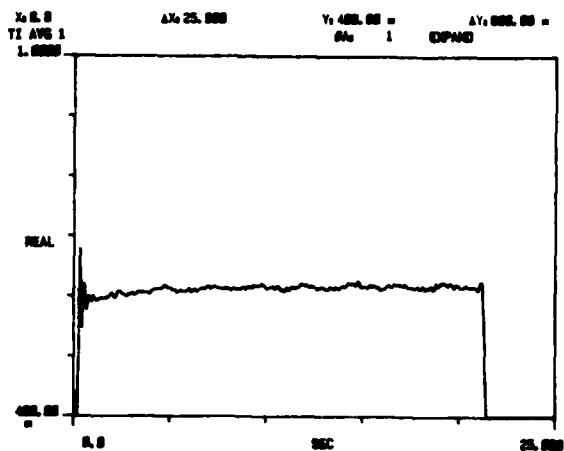
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 SCALE ABS. Time in Seconds
 SPEED 3.4 fps(ms) 8.8 kts(fs)
 CONFIG. Bare Hull



DATE 4-13-79
 RUN NO. 0 - 1
 CHAN NO. 4 STBD RPM
 ICE TH. .5 in(ms) 9.55 in(fs)
 SCALE ORD. 1 volt = 400 RPM
 SCALE ABS. Time in Seconds
 SPEED 3.4 fps(ms) 8.8 kts(fs)
 CONFIG. Bare Hull



DATE 4-13-79
 RUN NO. 0 - 1
 CHAN NO. 5 Speed
 ICE TH. .5 in(ms) 9.55 in(fs)
 SCALE ORD. 1 volt = 5 fps(ms) ~13 kts
 SCALE ABS. Time in Seconds
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 CONFIG. Bare Hull



DATE 4-13-79

RUN NO. 0 - 2

CHAN NO. 1 Port RPM

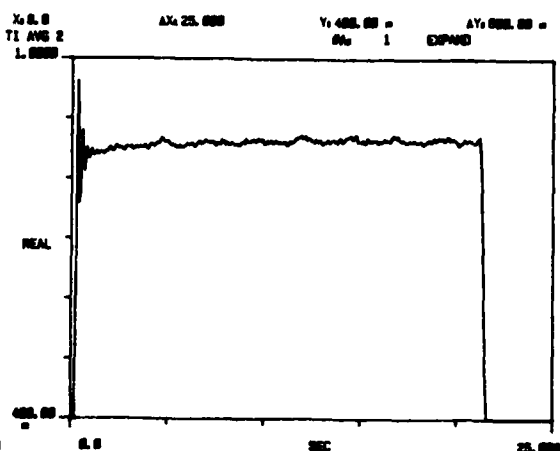
ICE TH. .5 in(ms) 9.55 in(fs)

SCALE ORD. 1 volt = 400 RPM

SCALE ABS. Time in Seconds

SPEED .9 fps(ms) 2.4 kts (fs)

CONFIG. Bare Hull



DATE 4-13-79

RUN NO. 0 - 2

CHAN NO. 2 Stbd RPM

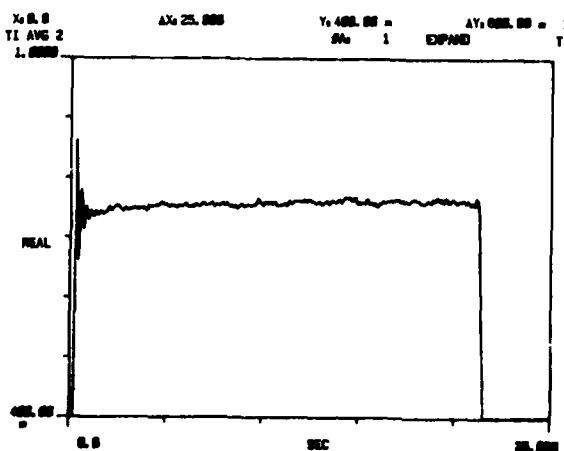
ICE TH. .5 in(ms) 9.55 in(fs)

SCALE ORD. 1 volt = 400 RPM

SCALE ABS. Time in Seconds

SPEED .9 fps(ms) 2.4 kts (fs)

CONFIG. Bare Hull



DATE 4-13-79

RUN NO. 0 - 2

CHAN NO. 4 STBD RPM

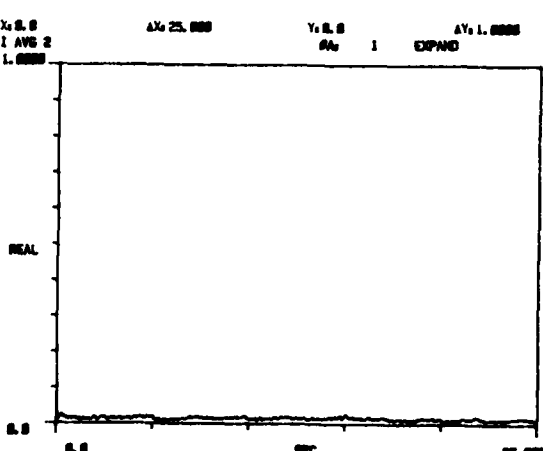
ICE TH. .5 in(ms) 9.55 in(fs)

SCALE ORD. 1 volt = 400 RPM

SCALE ABS. Time in Seconds

SPEED .9 fps(ms) 2.4 kts (fs)

CONFIG. Bare Hull



DATE 4-13-79

RUN NO. 0 - 2

CHAN NO. 5 Speed

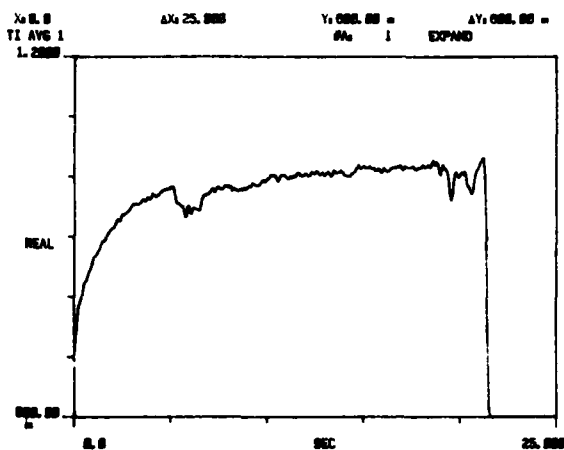
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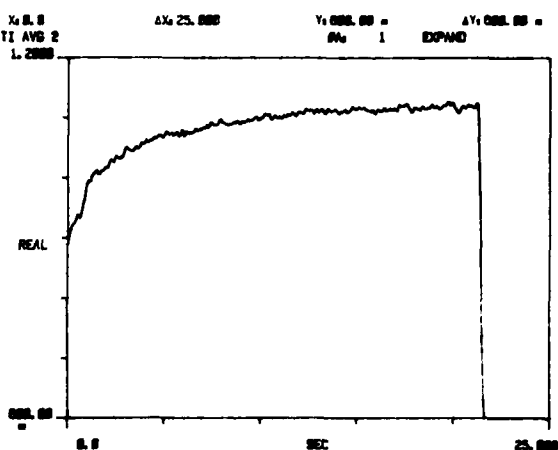
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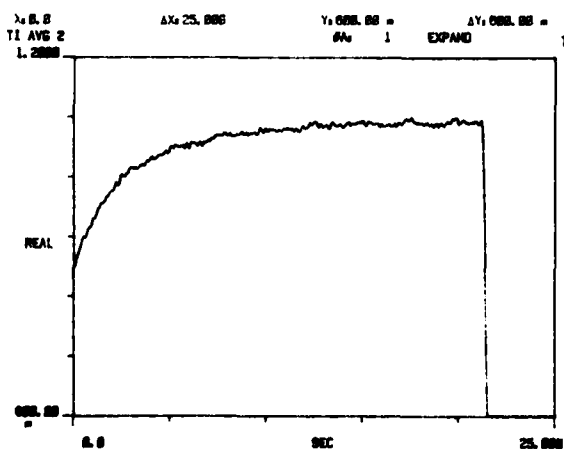
CONFIG. Bare Hull



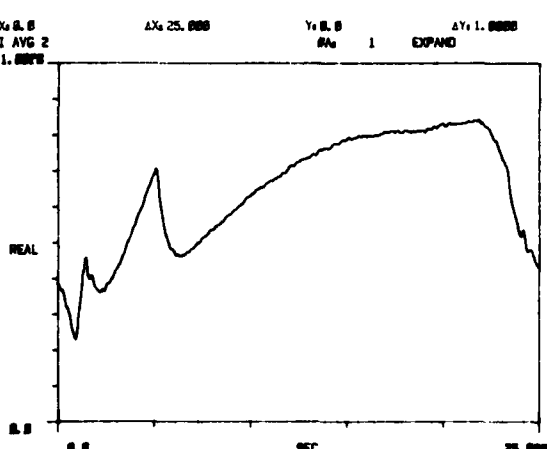
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 SCALE ABS. Time in Seconds
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 CONFIG. Bare Hull



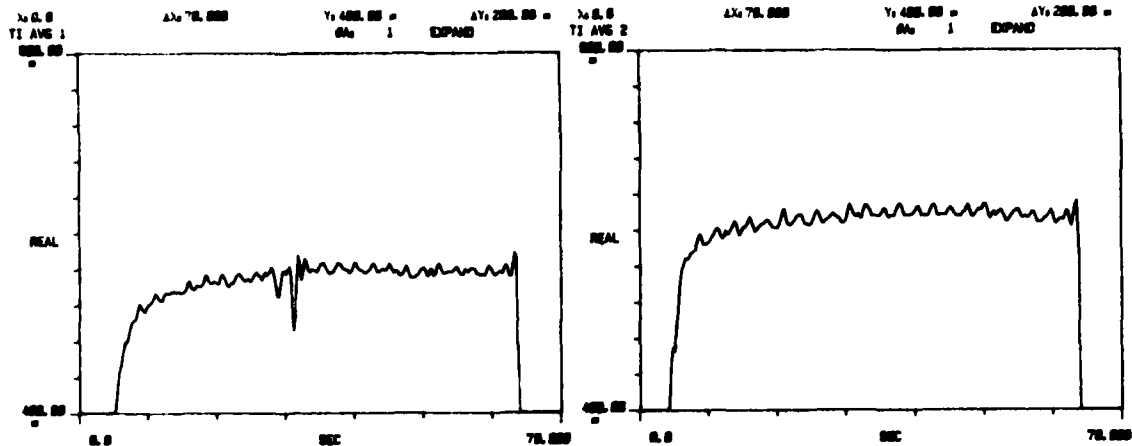
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 SCALE ORD. 1 volt = 400 RPM
 SCALE ABS. Time in Seconds
 SPEED 3.2 fps(ms) 8.2 kts(fs)
 CONFIG. Bare Hull



DATE 4-17-79
 RUN NO. 1 - 1
 CHAN NO. 4 STBD RPM
 ICE TH. .55 in(ms) 10.0 in(fs)
 SCALE ORD. 1 volt = 400 RPM
 SCALE ABS. Time in Seconds
 SPEED 3.2 fps(ms) 8.2 kts(fs)
 CONFIG. Bare Hull

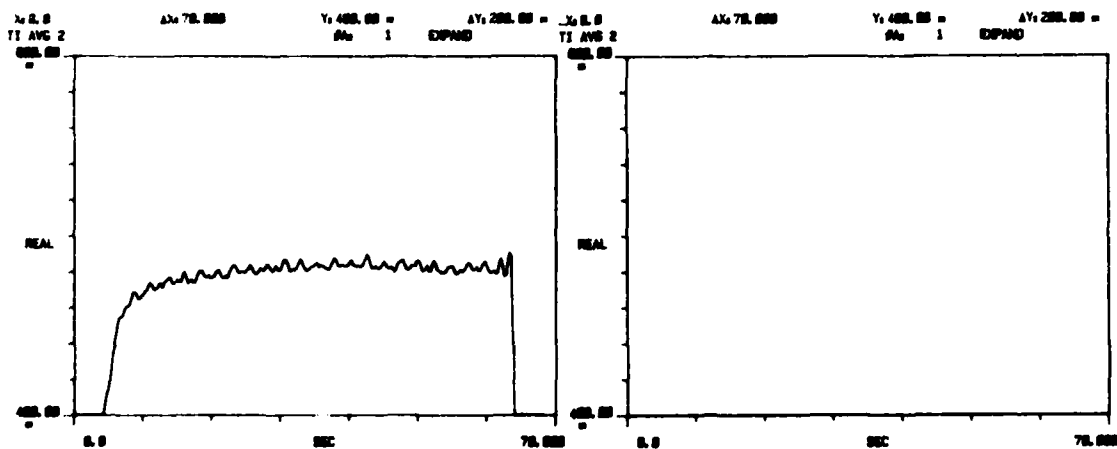


DATE 4-17-79
 RUN NO. 1 - 1
 CHAN NO. 5 Speed
 ICE TH. .55 in(ms) 10.0 in(fs)
 SCALE ORD. 1 volt=5 fps(ms)=13 kts(fs)
 SCALE ABS. Time in Seconds
 SPEED 3.2 fps(ms) 8.2 kts(fs)
 CONFIG. Bare Hull



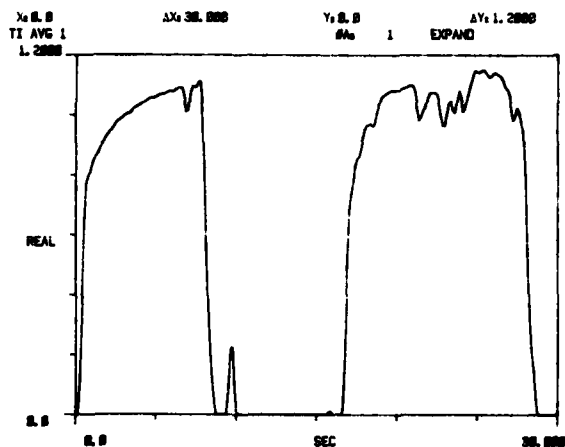
DATE 4-17-79
 RUN NO. 1 - 2
 CHAN NO. 1 Port rpm
 ICE TH. .55 in(ms) 10 in(fs)
 SCALE ORD. 1 volt = 400 RPM
 SCALE ABS. Time in Seconds
 SPEED 1 fps(ms) 2.5 kts(fs)
 CONFIG. Bare Hull

DATE 4-17-79
 RUN NO. 1 - 2
 CHAN NO. 2 6 RPM
 ICE TH. .95 in(ms) 10 in(fs)
 SCALE ORD. 1 volt = 400 RPM
 SCALE ABS. Time in Seconds
 SPEED 1 fps(ms) 2.5 kts(fs)
 CONFIG. Bare Hull



DATE 4-17-79
 RUN NO. 1 - 2
 CHAN NO. 4 STBD RPM
 ICE TH. .95 in(ms) 10 in(fs)
 SCALE ORD. 1 volt = 400 RPM
 SCALE ABS. Time in Seconds
 SPEED 1 fps(ms) 2.5 kts(fs)
 CONFIG. Bare Hull

DATE 4-17-79
 RUN NO. 1 - 2
 CHAN NO. 5 Speed
 ICE TH. .95 in(ms) 10.0 in(fs)
 SCALE ORD. 1 volt = 5fps(ms) 13 kts(fs)
 SCALE ABS. Time in Seconds
 SPEED 1 fps(ms) 2.5 kts(fs)
 CONFIG. Bare Hull



DATE 4-18-79

RUN NO. 2 1

CHAN NO. 1 Port RPM

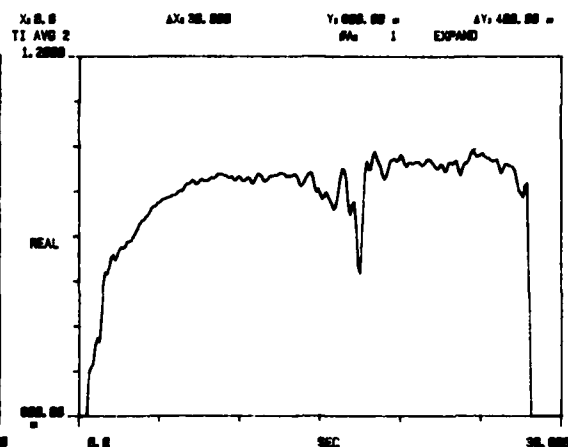
ICE TH. 1.14 in 22.9 in(fs)

SCALE ORD. 1 volt = 400 RPM

SCALE ABS. Time in Seconds

SPEED 2.4 fps(ms) 6.1 kts(fs)

CONFIG. Bare Hull



DATE 4-18-79

RUN NO. 2 1

CHAN NO. 2 6 RPM

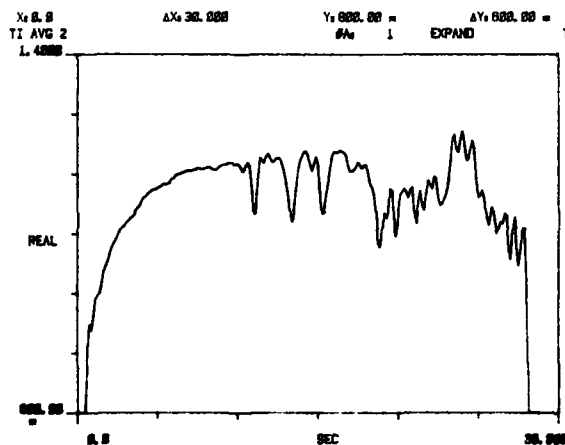
ICE TH. 1.14 in(ms) 22.9 in(fs)

SCALE ORD. 1 volt = 400 RPM

SCALE ABS. Time in Seconds

SPEED 2.4 fps(ms) 6.1 kts(fs)

CONFIG. Bare Hull



DATE 4-18-79

RUN NO. 2 1

CHAN NO. 4 STBD RPM

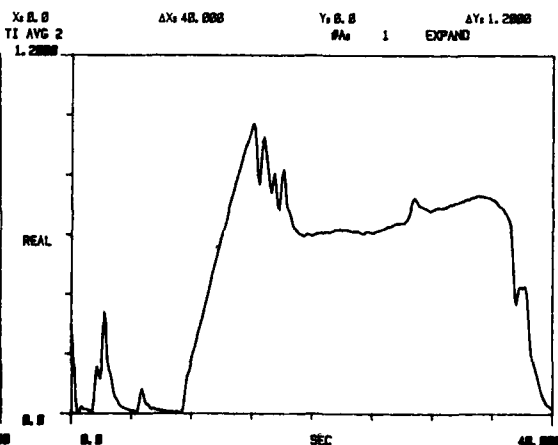
ICE TH. 1.14 in(ms) 22.9 in(fs)

SCALE ORD. 1 volt = 400 RPM

SCALE ABS. Time in Seconds

SPEED 2.4 fps(ms) 6.1 kts(fs)

CONFIG. Bare Hull



DATE 4-18-79

RUN NO. 2 1

CHAN NO. 5 Speed

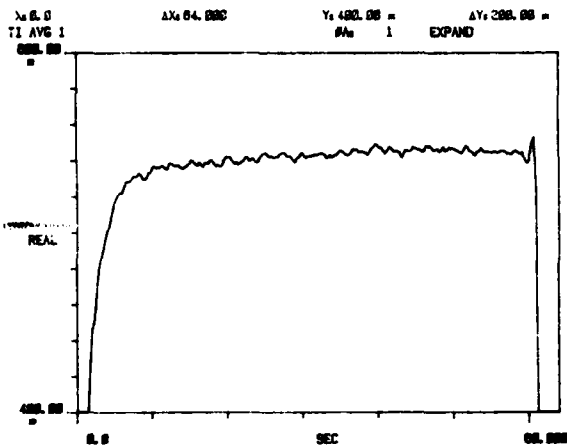
ICE TH. 1.14 in(ms) 22.9 in(fs)

SCALE ORD. 1 volt = 5 fps(ms) ~13 kts(fs)

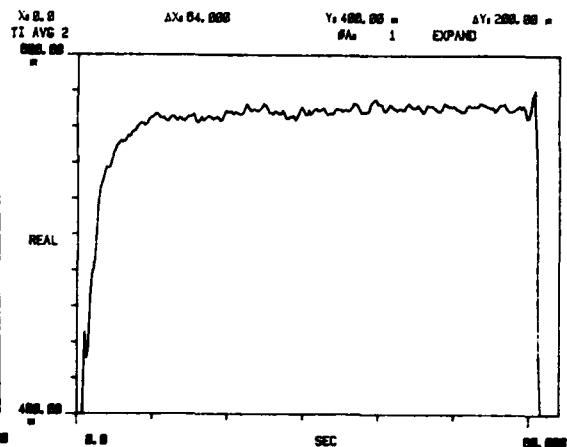
SCALE ABS. Time in Seconds

SPEED 2.4 fps(ms) 6.1 kts(fs)

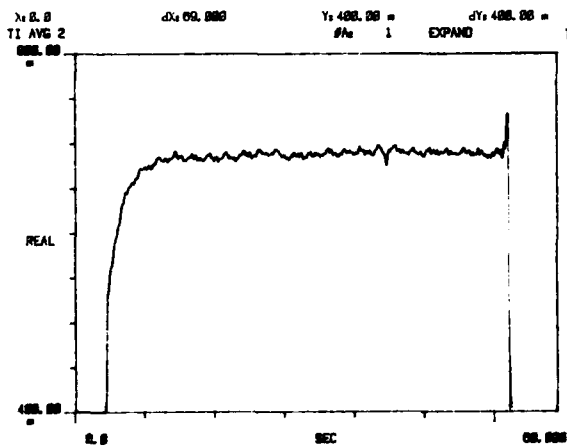
CONFIG. Bare Hull



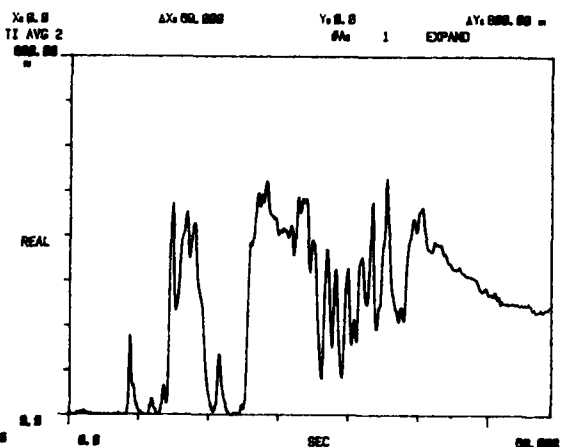
DATE 4-18-79
 RUN NO. 2 2
 CHAN NO. 1 Port RPM
 ICE TH. 1.14 in(ms) 22.9 in(fs)
 SCALE ORD. 1 volt = 400 RPM
 SCALE ABS. Time in Seconds
 SPEED 1.14 fps(ms) 2.9 kts(fs)
 CONFIG. Bare Hull



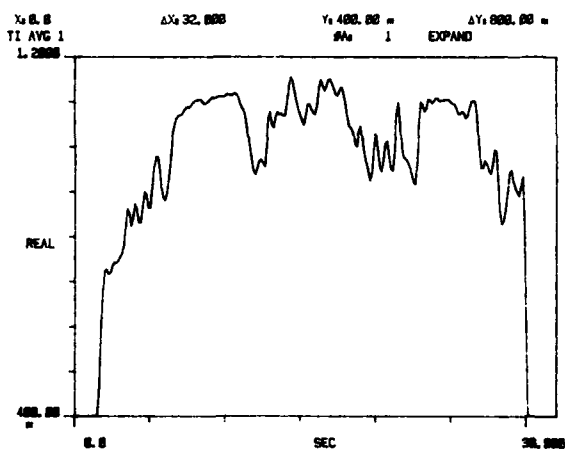
DATE 4-18-79
 RUN NO. 2 2
 CHAN NO. 2 6 RPM
 ICE TH. 1.14 in(ms) 22.9 in(fs)
 SCALE ORD. 1 volt = 400 RPM
 SCALE ABS. Time in Seconds
 SPEED 1.14 fps(ms) 2.9 kts(fs)
 CONFIG. Bare Hull



DATE 4-18-79
 RUN NO. 2 2
 CHAN NO. 4 STBD RPM
 ICE TH. 1.14 in(ms) 22.9 in(fs)
 SCALE ORD. 1 volt = 400 RPM
 SCALE ABS. Time in Seconds
 SPEED 1.14 fps(ms) 2.9 kts(fs)
 CONFIG. Bare Hull



DATE 4-18-79
 RUN NO. 2 2
 CHAN NO. 5 Speed
 ICE TH. 1.14 in(ms) 22.9 in(fs)
 SCALE ORD. 1 volt = 5 fps(ms) ~13 kts(fs)
 SCALE ABS. Time in Seconds
 SPEED 1.14 fps(ms) 2.9 kts(fs)
 CONFIG. Bare Hull



DATE 4-19-79

RUN NO. 3 1

CHAN NO. 1 Port RPM

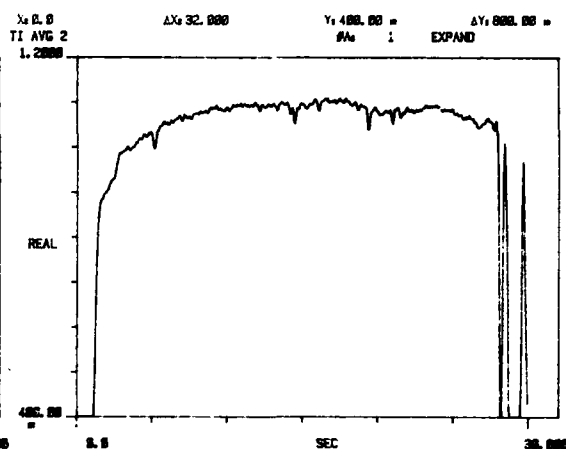
ICE TH. 1.02 in(ms) 20.4 in(fs)

SCALE ORD. 1 volt = 400 RPM

SCALE ABS. Time in Seconds

SPEED 3 fps(ms) 7.7 kts(fs)

CONFIG. Fins



DATE 4-19-79

RUN NO. 3 1

CHAN NO. 2 6 RPM

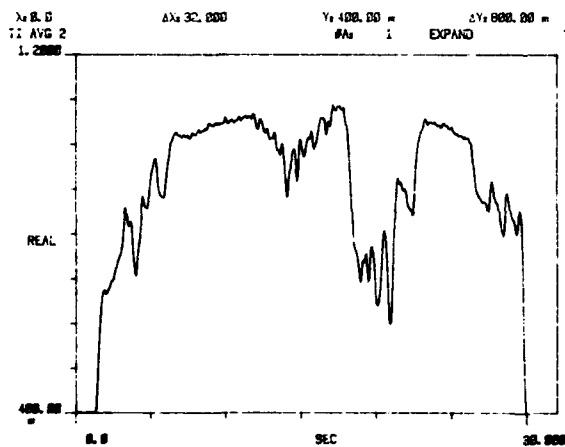
ICE TH. 1.02 in(ms) 20.4 in(fs)

SCALE ORD. 1 volt = 400 RPM

SCALE ABS. Time in Seconds

SPEED 3 fps(ms) 7.7 kts(fs)

CONFIG. Fins



DATE 4-19-79

RUN NO. 3 1

CHAN NO. 4 STBD RPM

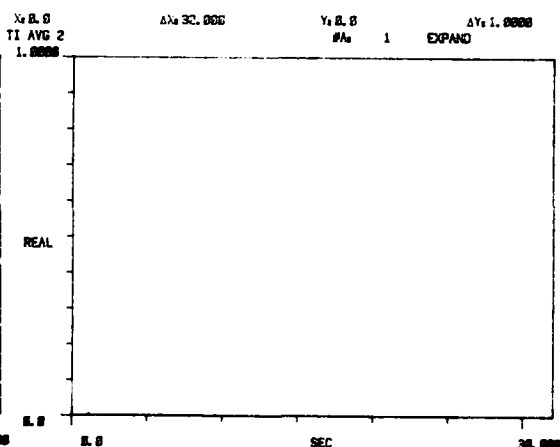
ICE TH. 1.02 in(ms) 20.4 in(fs)

SCALE ORD. 1 volt = 400 RPM

SCALE ABS. Time in Seconds

SPEED 3 fps(ms) 7.7 kts(fs)

CONFIG. Fins



DATE 4-19-79

RUN NO. 3 1

CHAN NO. 5 Speed

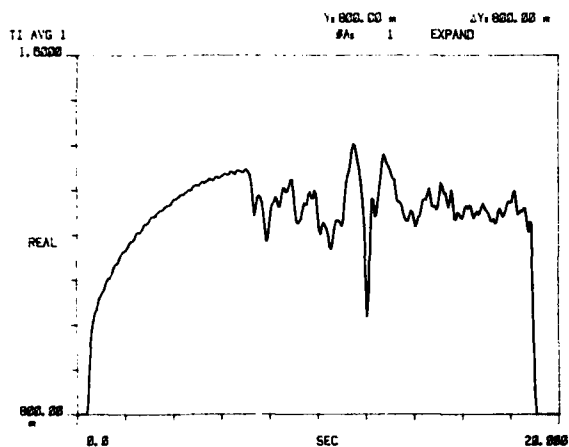
ICE TH. 1.02 in(ms) 20.4 in(fs)

SCALE ORD. 1 volt = 5 fps(ms) 13 kts(fs)

SCALE ABS. Time in Seconds

SPEED 3 fps(ms) 7.7 kts(fs)

CONFIG. Fins



DATE 4-19-79

RUN NO. 3 2

CHAN NO. 1 Part RPM

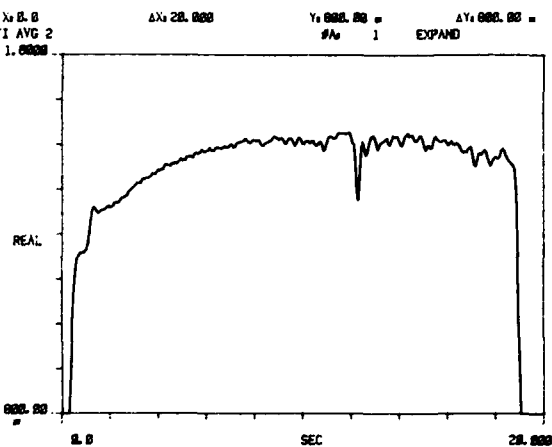
ICE TH. 1.02 in(ms) 20.4 in(fs)

SCALE ORD. 1 volt = 400 RPM

SCALE ABS. Time in Seconds

SPEED 3 fps(ms) 7.5 kts(fs)

CONFIG. Fins



DATE 4-19-79

RUN NO. 3 2

CHAN NO. 2 C RPM

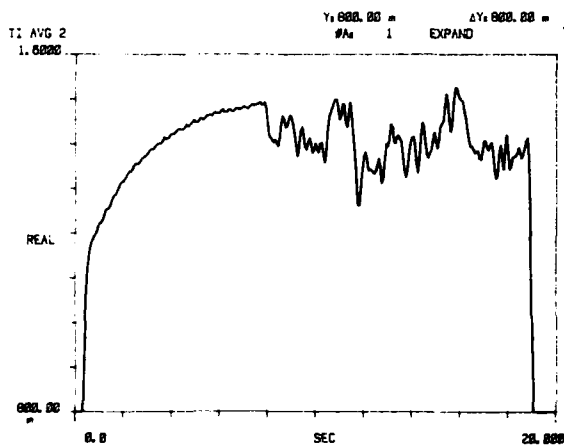
ICE TH. 1.02 in(ms) 20.4 in(fs)

SCALE ORD. 1 volt = 400 RPM

SCALE ABS. Time in Seconds

SPEED 3 fps(ms) 7.5 kts(fs)

CONFIG. Fins



DATE 4-19-79

RUN NO. 3 2

CHAN NO. 4 STBD RPM

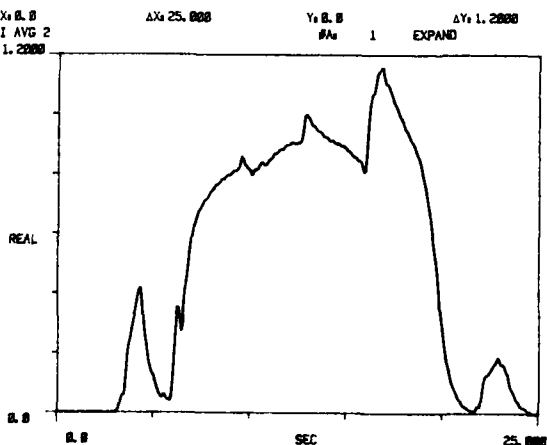
ICE TH. 1.02 in(ms) 20.4 in(fs)

SCALE ORD. 1 volt = 400 RPM

SCALE ABS. Time in Seconds

SPEED 3 fps(ms) 7.5 kts(fs)

CONFIG. Fins



DATE 4-19-79

RUN NO. 3 2

CHAN NO. 5 Speed

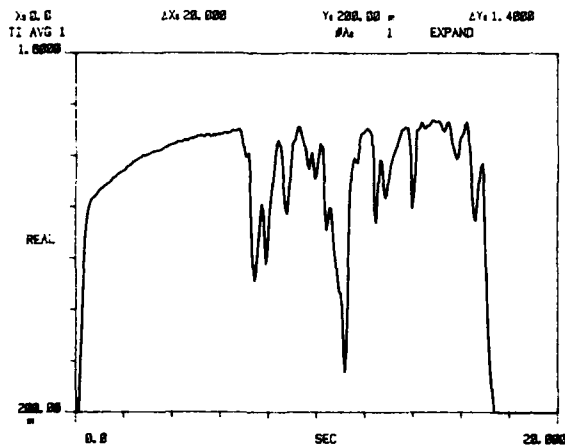
ICE TH. 1.02 in(ms) 20.4 in(fs)

SCALE ORD. 1 volt = 5 fps(ms) ~13 kts(fs)

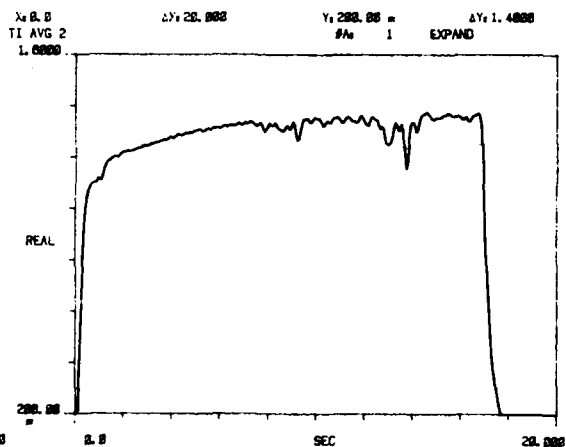
SCALE ABS. Time in Seconds

SPEED 3 fps(ms) 7.5 kts(fs)

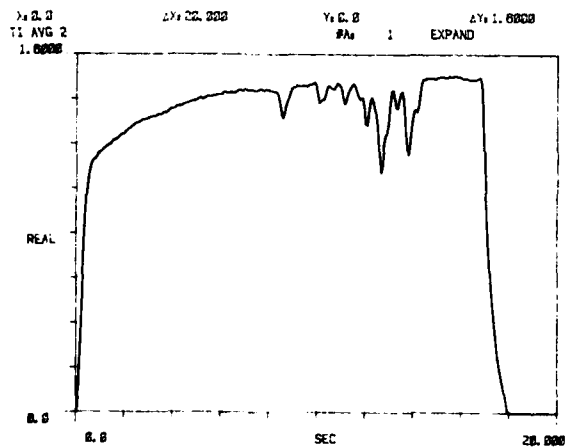
CONFIG. Fins



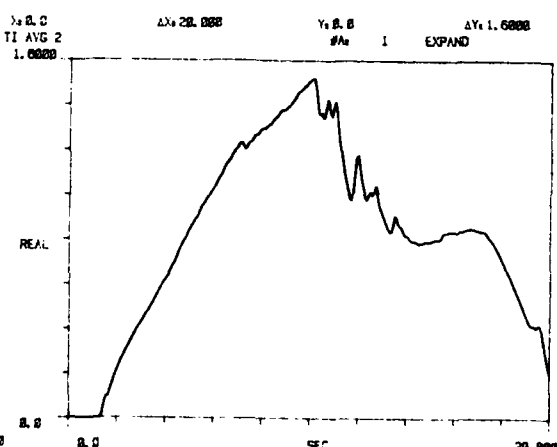
DATE 4-20-79
 RUN NO. 4 1
 CHAN NO. 1 Port RPM
 ICE TH. 1.02 in(ms) 20.4 in(fs)
 SCALE ORD. 1 volt = 400 RPM
 SCALE ABS. Time in Seconds
 SPEED 4.6 fps(ms) 7.6 kts(fs)
 CONFIG. Reverse Rotation



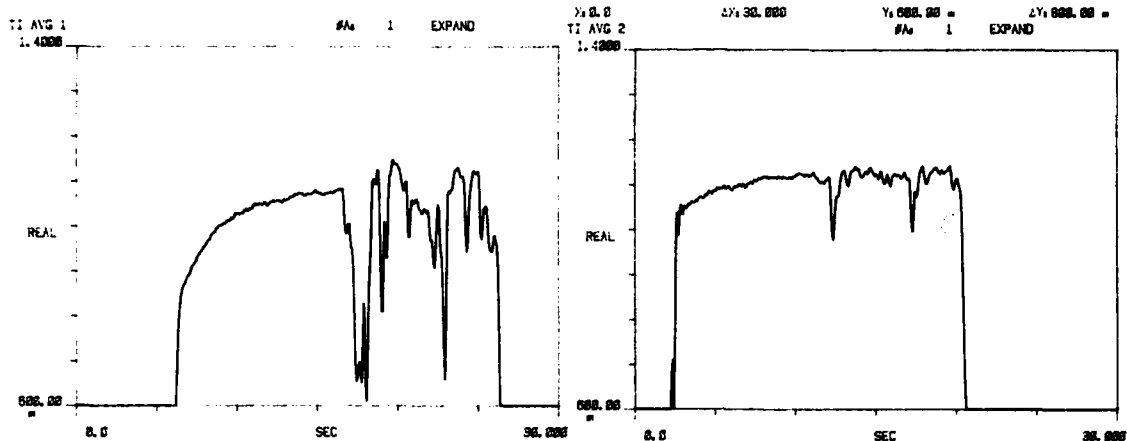
DATE 4-20-79
 RUN NO. 4 1
 CHAN NO. 2 6 RPM
 ICE TH. 1.02 in(ms) 20.4 in(fs)
 SCALE ORD. 1 volt = 400 RPM
 SCALE ABS. Time in Seconds
 SPEED 4.6 fps(ms) 7.6 kts(fs)
 CONFIG. Reverse Rotation



DATE 4-20-79
 RUN NO. 4 1
 CHAN NO. 4 STRD RPM
 ICE TH. 1.02 in(ms) 20.4 in(fs)
 SCALE ORD. 1 volt = 400 RPM
 SCALE ABS. Time in Seconds
 SPEED 4.6 fps(ms) 7.6 kts(fs)
 CONFIG. Reverse Rotation

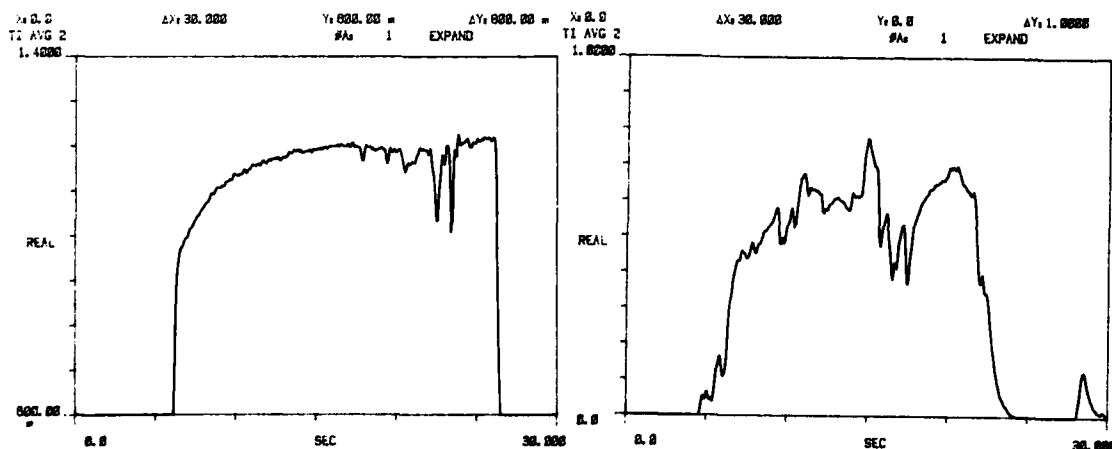


DATE 4-20-79
 RUN NO. 4 1
 CHAN NO. 5 Speed
 ICE TH. 1.02 in(ms) 20.4 in(fs)
 SCALE ORD. 1 volt = 5 fps(ms) ~13 kts(fs)
 SCALE ABS. Time in Seconds
 SPEED 4.6 fps(ms) 7.6 kts(fs)
 CONFIG. Reverse Rotation



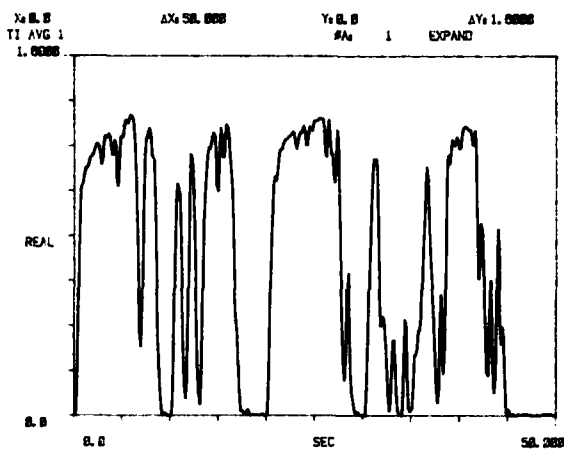
DATE 4-20-79
 RUN NO. 4 2
 CHAN NO. 2 Port RPM
 ICE TH. 1.02 in(ms) 20.4 in(fs)
 SCALE ORD. 1 volt = 400 RPM
 SCALE ABS. Time in Seconds
 SPEED 2.3 fps(ms) 5.9 kts(fs)
 CONFIG. Reverse Rotation

DATE 4-20-79
 RUN NO. 4 2
 CHAN NO. 2 4 RPM
 ICE TH. 1.02 in(ms) 20.4 in(fs)
 SCALE ORD. 1 volt = 400 RPM
 SCALE ABS. Time in Seconds
 SPEED 2.3 fps(ms) 5.9 kts(fs)
 CONFIG. Reverse Rotation



DATE 4-20-79
 RUN NO. 4 2
 CHAN NO. 4 STBD RPM
 ICE TH. 1.02 in(ms) 20.4 in(fs)
 SCALE ORD. 1 volt = 400 RPM
 SCALE ABS. Time in Seconds
 SPEED 2.3 fps(ms) 5.9 kts(fs)
 CONFIG. Reverse Rotation

DATE 4-20-79
 RUN NO. 4 2
 CHAN NO. 5 Speed
 ICE TH. 1.02 in(ms) 20.4 in(fs)
 SCALE ORD. 1 volt = 5fps(ms) ~ 13 kts(fs)
 SCALE ABS. Time in Seconds
 SPEED 2.3 fps(ms) 5.9 kts(fs)
 CONFIG. Reverse Rotation



DATE 4-23-79

RUN NO. 5 1

CHAN NO. 1 Port RPM

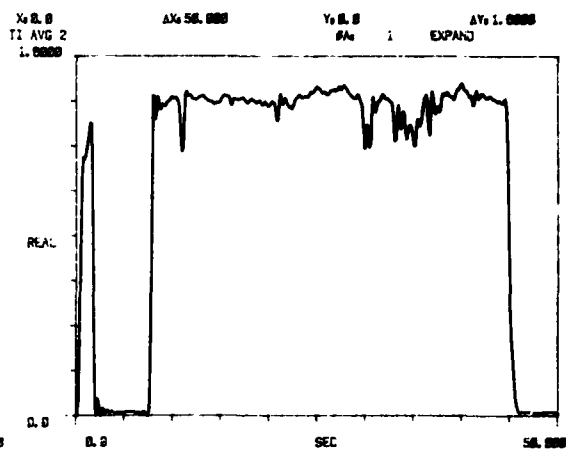
ICE TH. 2 in(ms) 40 in(fs)

SCALE ORD. 1 volt = 400 RPM

SCALE ABS. Time in Seconds

SPEED 2.5 fps(ms) 6.5 kts(fs)

CONFIG. Bird Cages



DATE 4-23-79

RUN NO. 5 1

CHAN NO. 2 6 RPM

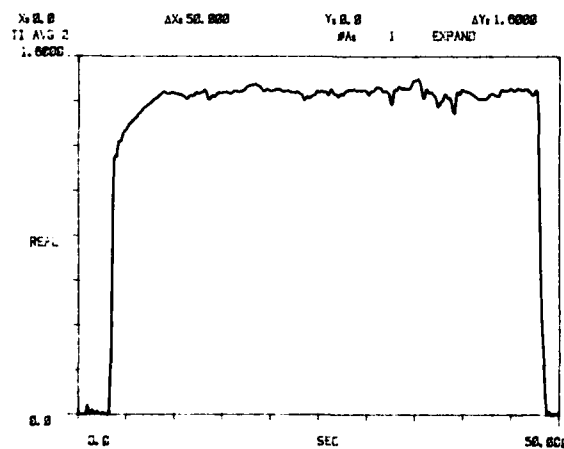
ICE TH. 2 in(ms) 40 in(fs)

SCALE ORD. 1 volt = 400 RPM

SCALE ABS. Time in Seconds

SPEED 2.5 fps(ms) 6.5 kts(fs)

CONFIG. Bird Cages



DATE 4-23-79

RUN NO. 5 1

CHAN NO. 4 STBD RPM

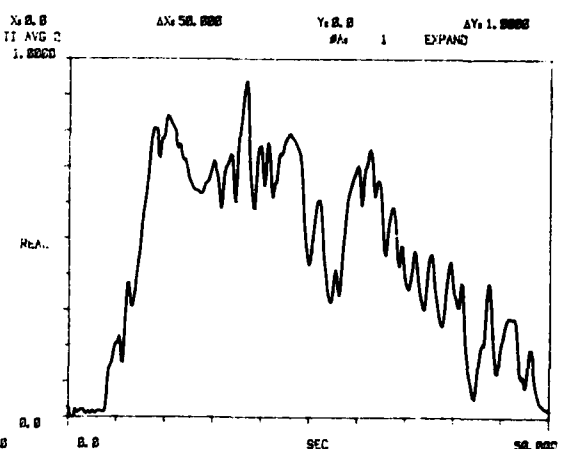
ICE TH. 2 in(ms) 40 in(fs)

SCALE ORD. 1 volt = 400 RPM

SCALE ABS. Time in Seconds

SPEED 2.5 fps(ms) 6.5 kts(fs)

CONFIG. Bird Cages



DATE 4-23-79

RUN NO. 5 1

CHAN NO. 5 Speed

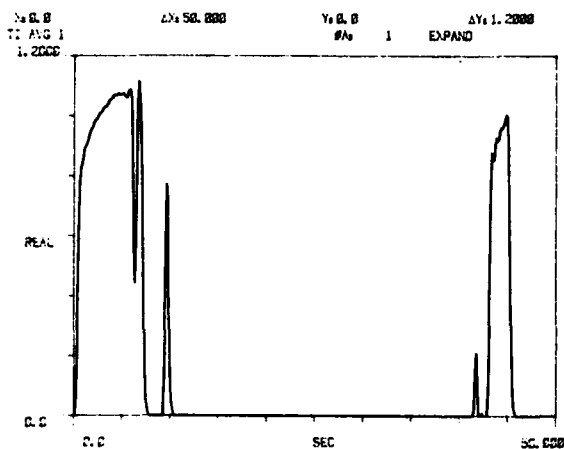
ICE TH. 2 in(ms) 40 in(fs)

SCALE ORD. 1 volt = 5 fps(ms) ~12 kts(fs)

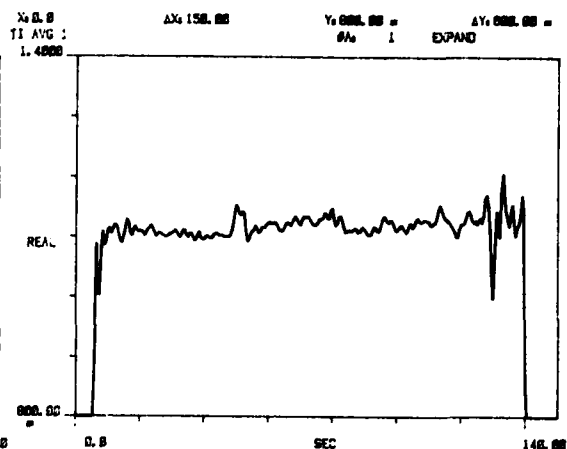
SCALE ABS. Time in Seconds

SPEED 2.5 fps(ms) 6.5 kts(fs)

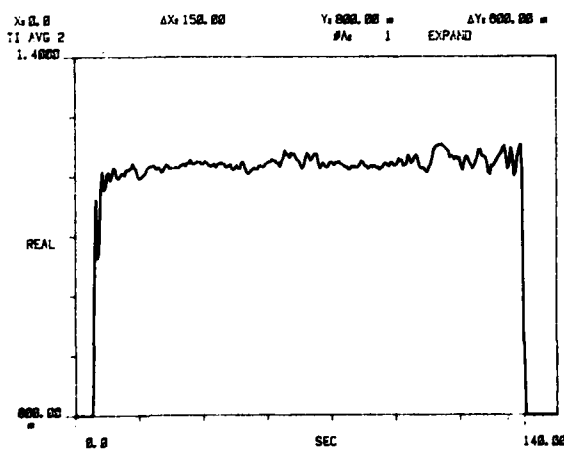
CONFIG. Bird Cages



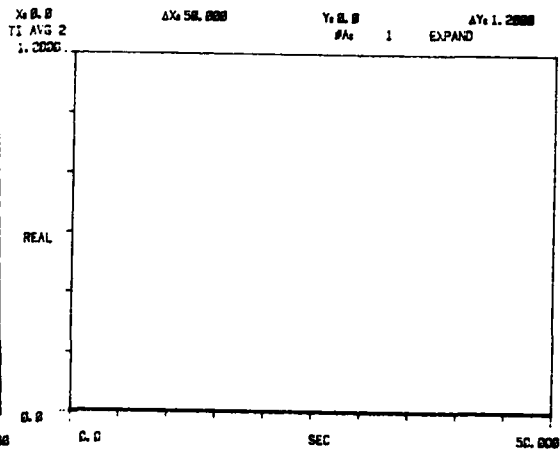
DATE 4-23-79
 RUN NO. 5 2
 CHAN NO. 1 Port RPM
 ICE TH. 2 in(ms) 40 in(fs)
 SCALE ORD. 1 volt = 400 RPM
 SCALE ABS. Time in Seconds
 SPEED 1.7 fps(ms) 4.5 kts(fs)
 CONFIG. Bird Cages



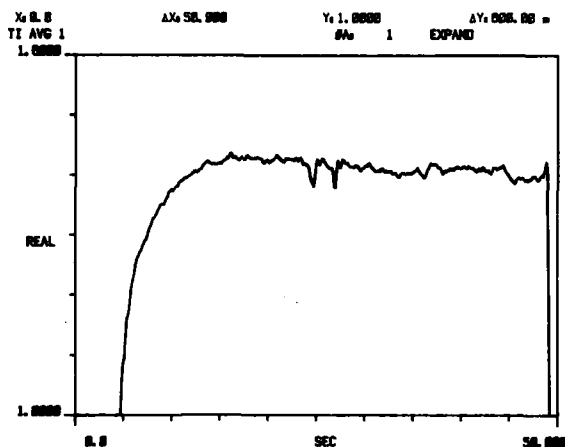
DATE 4-23-79
 RUN NO. 5 2
 CHAN NO. 2 STBD RPM
 ICE TH. 2 in(ms) 40 in(fs)
 SCALE ORD. 1 volt = 400 RPM
 SCALE ABS. Time in Seconds
 SPEED 1.7 fps(ms) 4.5 kts(fs)
 CONFIG. Bird Cages



DATE 4-23-79
 RUN NO. 5 2
 CHAN NO. 4 STBD RPM
 ICE TH. 2 in(ms) 40 in(fs)
 SCALE ORD. 1 volt = 400 RPM
 SCALE ABS. Time in Seconds
 SPEED 1.7 fps(ms) 4.5 kts(fs)
 CONFIG. Bird Cages



DATE 4-23-79
 RUN NO. 5 2
 CHAN NO. 5 Speed
 ICE TH. 2 in(ms) 40 in(fs)
 SCALE ORD. 1 volt = 5 fps(ms) ~13 kts(fs)
 SCALE ABS. Time in Seconds
 SPEED 1.7 fps(ms) 4.5 kts(fs)
 CONFIG. Bird Cages



DATE 4-25-79

RUN NO. 6 1

CHAN NO. 1 Port RPM

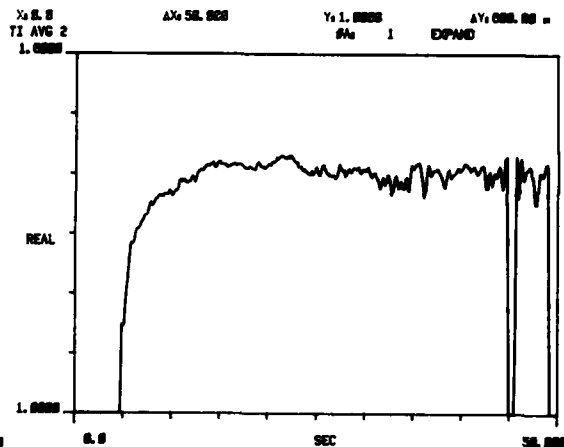
ICE TH. 1.5 in(ms) 36 in(fs)

SCALE ORD. 1 volt = 400 RPM

SCALE ABS. Time in Seconds

SPEED 2.0 fps(ms) 5 kts(fs)

CONFIG. Large Bilge Keels



DATE 4-25-79

RUN NO. 6 1

CHAN NO. 2 6 RPM

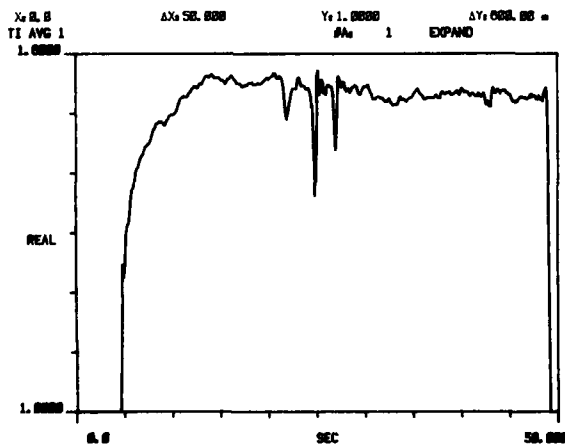
ICE TH. 1.0 in(ms) 36 in(fs)

SCALE ORD. 1 volt = 400 RPM

SCALE ABS. Time in Seconds

SPEED 2 fps(ms) 5 kts(fs)

CONFIG. Large Bilge Keels



DATE 4-25-79

RUN NO. 6 1

CHAN NO. 4 STBD RPM

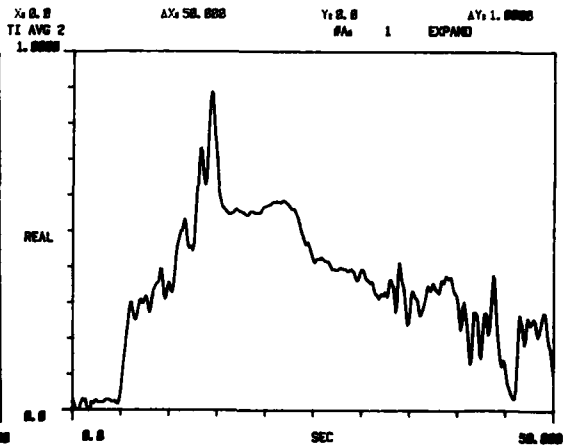
ICE TH. 1.8 in(ms) 36 in(fs)

SCALE ORD. 1 volt = 400 RPM

SCALE ABS. Time in Seconds

SPEED 2 fps(ms) 5 kts(fs)

CONFIG. Large Bilge Keels



DATE 4-25-79

RUN NO. 6 1

CHAN NO. 5 Speed

ICE TH. 1.8 in(ms) 36 in(fs)

SCALE ORD. 1 volt = 5 fps(ms) ~13 kts(fs)

SCALE ABS. Time in Seconds

SPEED 2 fps(ms) 5 kts(fs)

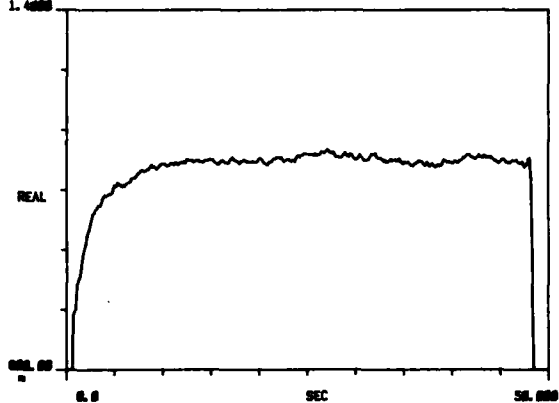
CONFIG. Large Bilge Keels

Y: 0.0
TI AVG 1
1.4000

ΔX: 50.000
Y: 000.00 =
#A: 1 EXPAND

X: 0.0
TI AVG 2
1.4000

ΔX: 50.000
Y: 000.00 =
#A: 1 EXPAND



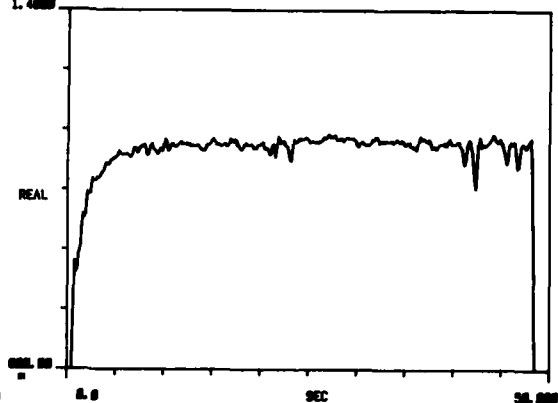
DATE 4-25-79
RUN NO. 6 2
CHAN NO. 1 Port RPM
ICE TH. 1.8 in(ms) 36 in(fs)
SCALE ORD. 1 volt = 400 RPM
SCALE ABS. Time in Seconds
SPEED 1.5 fps(ms) 3.85 kts(fs)
CONFIG. Large Bilge Keels

Y: 0.0
TI AVG 1
1.4000

ΔX: 50.000
Y: 000.00 =
#A: 1 EXPAND

X: 0.0
TI AVG 2
1.4000

ΔX: 50.000
Y: 000.00 =
#A: 1 EXPAND



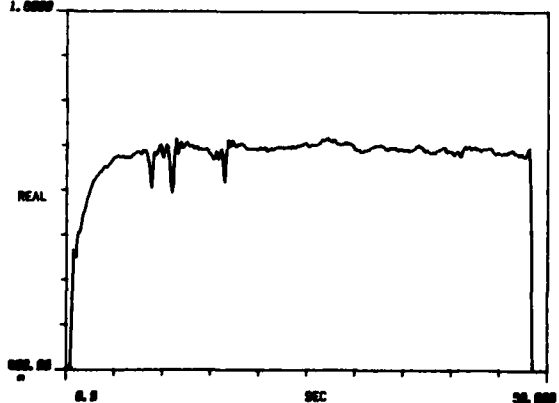
DATE 4-25-79
RUN NO. 6 2
CHAN NO. 2 5 RPM
ICE TH. 1.8 in(ms) 36 in(fs)
SCALE ORD. 1 volt = 400 RPM
SCALE ABS. Time in Seconds
SPEED 1.5 fps(ms) 3.85 kts(fs)
CONFIG. Large Bilge Keels

Y: 0.0
TI AVG 1
1.0000

ΔX: 50.000
Y: 000.00 =
#A: 1 EXPAND

X: 0.0
TI AVG 2
1.0000

ΔX: 50.000
Y: 000.00 =
#A: 1 EXPAND



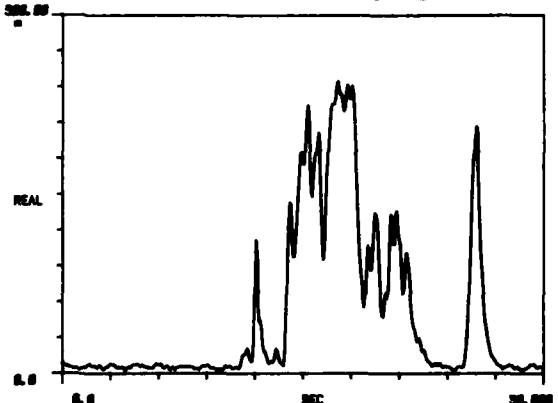
DATE 4-25-79
RUN NO. 6 2
CHAN NO. 4 STBD RPM
ICE TH. 1.8 in(ms) 36 in(fs)
SCALE ORD. 1 volt = 400 RPM
SCALE ABS. Time in Seconds
SPEED 1.5 fps(ms) 3.85 kts(fs)
CONFIG. Large Bilge Keels

Y: 0.0
TI AVG 1
1.0000

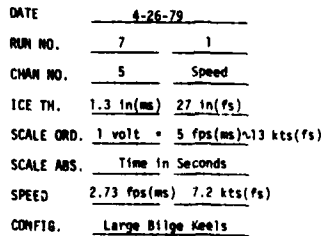
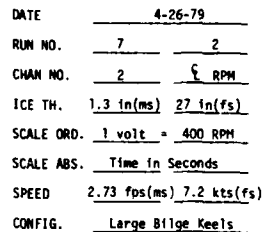
ΔX: 50.000
Y: 000.00 =
#A: 1 EXPAND

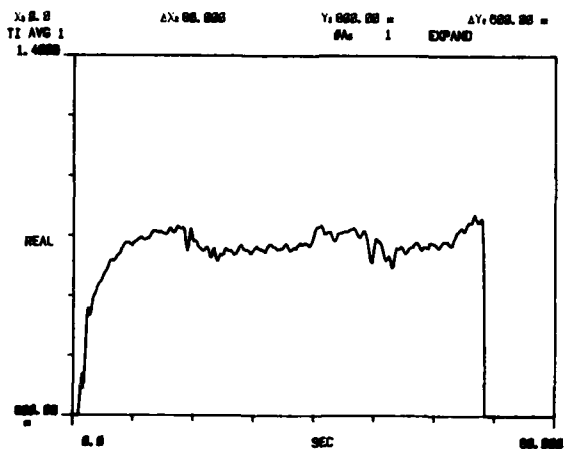
X: 0.0
TI AVG 2
1.0000

ΔX: 50.000
Y: 000.00 =
#A: 1 EXPAND

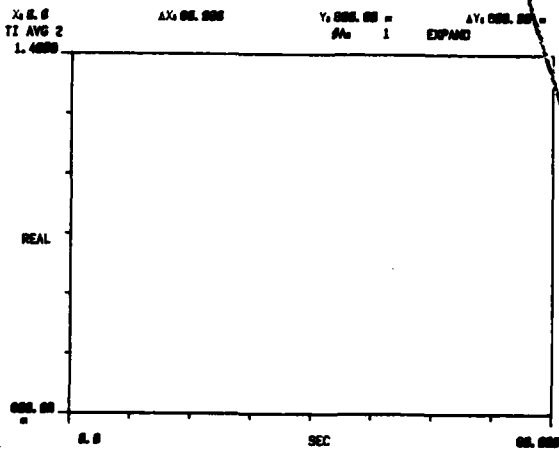


DATE 4-25-79
RUN NO. 6 2
CHAN NO. 5 Speed
ICE TH. 1.8 in(ms) 36 in(fs)
SCALE ORD. 1 volt = 5 fps(ms) ~13 kts(fs)
SCALE ABS. Time in Seconds
SPEED 1.5 fps(ms) 3.85 kts(fs)
CONFIG. Large Bilge Keels

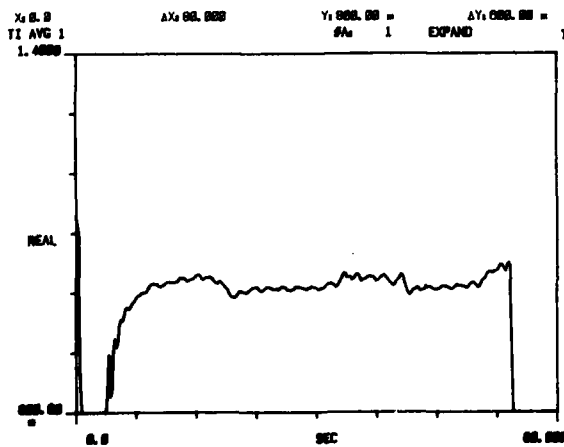




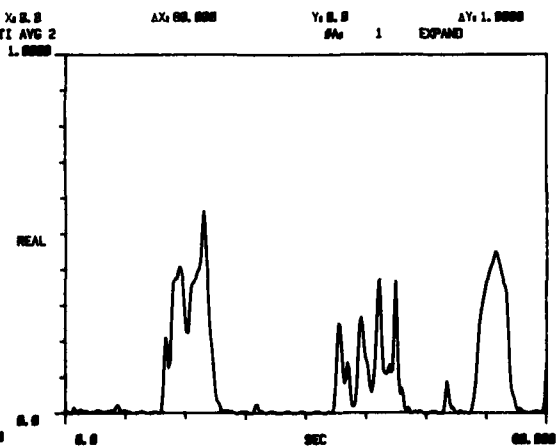
DATE 4-26-79
 RUN NO. 7 2
 CHAN NO. 1 Port RPM
 ICE TH. 1.3 in(ms) 27 in(fs)
 SCALE ORD. 1 volt = 400 RPM
 SCALE ABS. Time in Seconds
 SPEED 1 fps(ms) 2.88 kts(fs)
 CONFIG. Large Bilge Keels



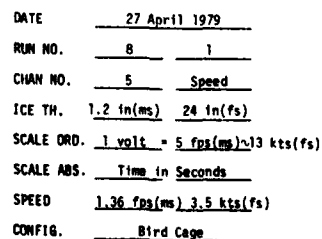
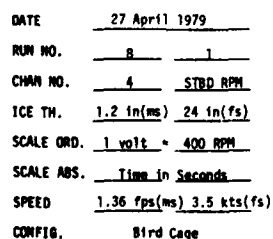
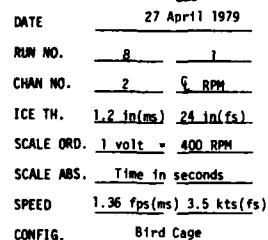
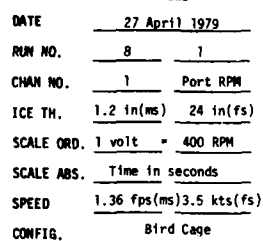
DATE 4-26-79
 RUN NO. 7 2
 CHAN NO. 2 0 RPM
 ICE TH. 1.3 in(ms) 27 in(fs)
 SCALE ORD. 1 volt = 400 RPM
 SCALE ABS. Time in Seconds
 SPEED 1 fps(ms) 2.88 kts(fs)
 CONFIG. Large Bilge Keels

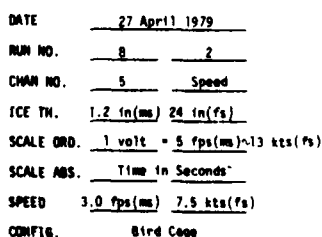
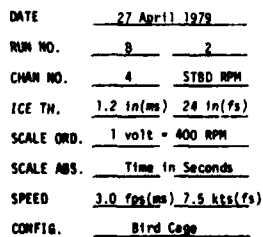
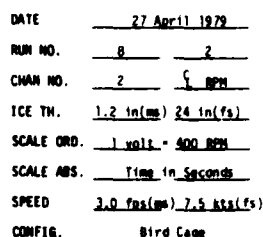
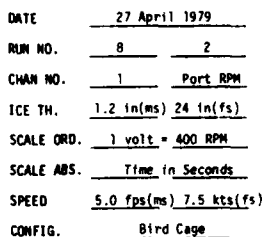


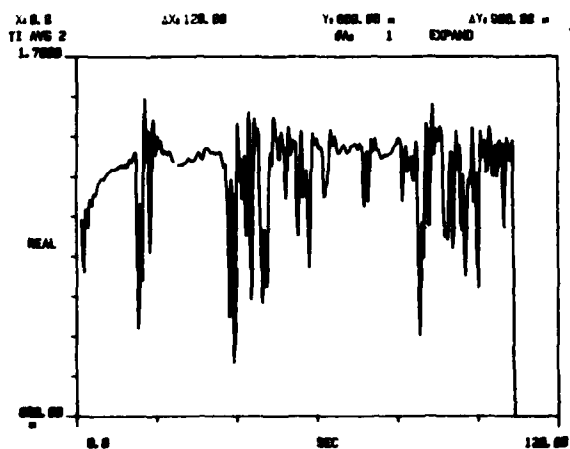
DATE 4-26-79
 RUN NO. 7 2
 CHAN NO. 4 STBD RPM
 ICE TH. 1.3 in(ms) 27 in(fs)
 SCALE ORD. 1 volt = 400 RPM
 SCALE ABS. Time in Seconds
 SPEED 1 fps(ms) 2.88 kts(fs)
 CONFIG. Large Bilge Keels



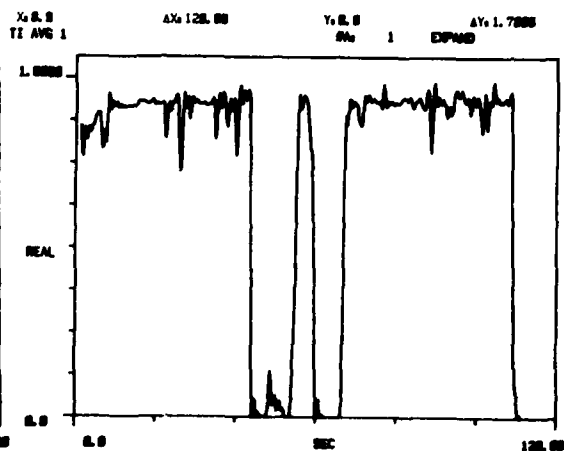
DATE 4-26-79
 RUN NO. 7 2
 CHAN NO. 5 Speed
 ICE TH. 1.3 in(ms) 27 in(fs)
 SCALE ORD. 1 volt = 5 fps(ms) ~13 kts(fs)
 SCALE ABS. Time in Seconds
 SPEED 1 fps(ms) 2.88 kts(fs)
 CONFIG. Large Bilge Keels



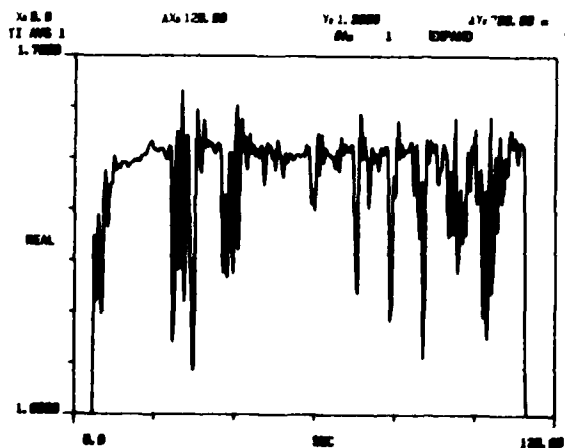




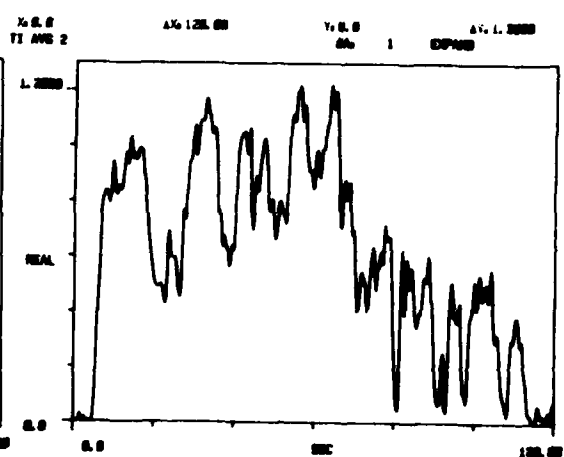
DATE 30 April 1979
 RUN NO. 9 1
 CHAN NO. 1 Port RPM
 ICE TH. 3.06 in(ms) 61.2 in(fs)
 SCALE ORD. 1 volt = 400 RPM
 SCALE ABS. Time in Seconds
 SPEED 3.6 fps(ms) 9.4 kts(fs)
 CONFIG. Bare Hull



DATE 30 April 1979
 RUN NO. 9 1
 CHAN NO. 2 S RPM
 ICE TH. 3.06 in(ms) 61.2 in(fs)
 SCALE ORD. 1 volt = 400 RPM
 SCALE ABS. Time in Seconds
 SPEED 3.6 fps(ms) 9.4 kts(fs)
 CONFIG. Bare Hull

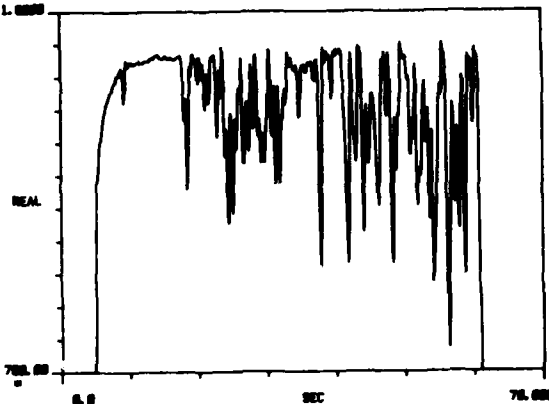


DATE 30 April 1979
 RUN NO. 9 1
 CHAN NO. 4 STBD RPM
 ICE TH. 3.06 in(ms) 61.2 in(fs)
 SCALE ORD. 1 volt = 400 RPM
 SCALE ABS. Time in Seconds
 SPEED 3.6 fps(ms) 9.4 kts(fs)
 CONFIG. Bare Hull



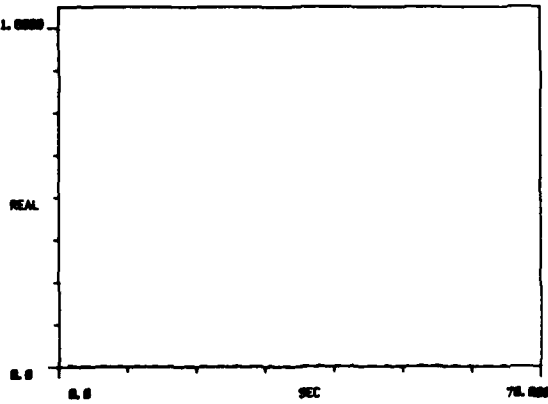
DATE 30 April 1979
 RUN NO. 9 1
 CHAN NO. 5 Speed
 ICE TH. 3.06 in(ms) 61.2 in(fs)
 SCALE ORD. 1 volt = 5 fps(ms) ~13 kts(fs)
 SCALE ABS. Time in Seconds
 SPEED 3.6 fps(ms) 9.4 kts(fs)
 CONFIG. Bare Hull

Ys 0.0
TI AVG 1
1.0000
ΔXs 75.000
Ys 750.00 =
0As 1
EXPAND
ΔYs 1.1000
Xs 0.0
TI AVG 2



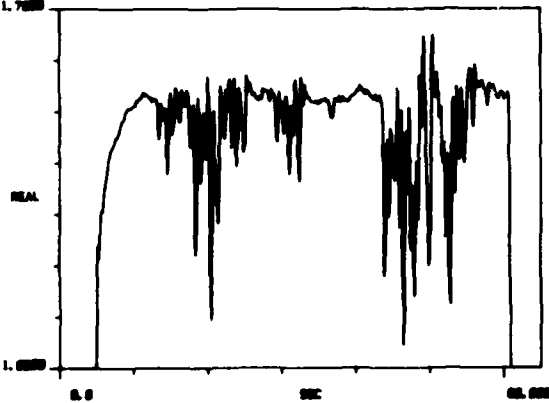
DATE 30 April 1979
RUN NO. 9 2
CHAN NO. 1 Port RPM
ICE TH. 3.06 in(ms) 61.2 in(fs)
SCALE ORD. 1 volt = 400 RPM
SCALE ABS. Time in Seconds
SPEED 1.6 fps(ms) 4.2 kts(fs)
CONFIG. Bare Hull

ΔXs 75.000
Ys 0.0
0As 1
EXPAND
ΔYs 1.7000
Xs 0.0
TI AVG 2



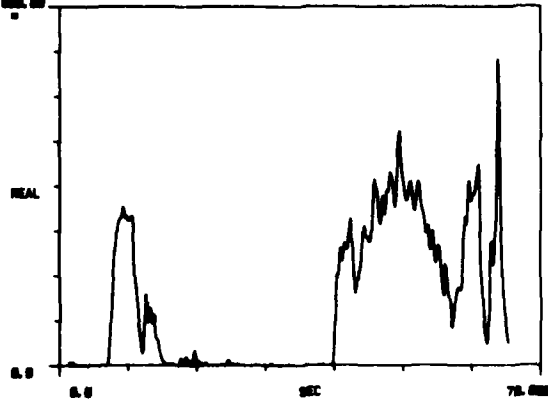
DATE 30 April 1979
RUN NO. 9 2
CHAN NO. 2 Q RPM
ICE TH. 3.06 in(ms) 61.2 in(fs)
SCALE ORD. 1 volt = 400 RPM
SCALE ABS. Time in Seconds
SPEED 1.6 fps(ms) 4.2 kts(fs)
CONFIG. Bare Hull

Ys 0.0
TI AVG 1
1.7000
ΔXs 05.000
Ys 1.0000
0As 1
EXPAND
ΔYs 700.00 =
Xs 0.0
TI AVG 2
000.00

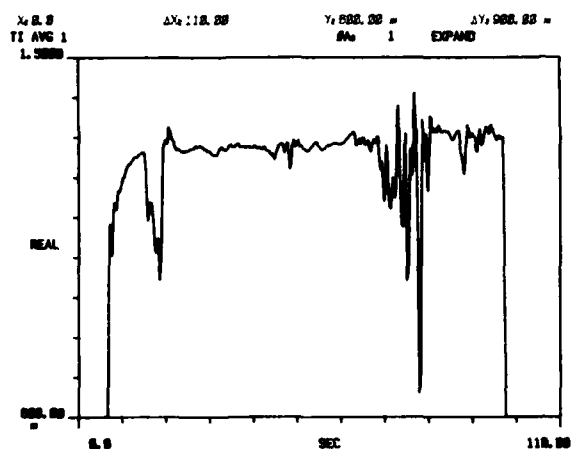


DATE 30 April 1979
RUN NO. 9 2
CHAN NO. 4 STBD RPM
ICE TH. 3.06 in(ms) 61.2 in(fs)
SCALE ORD. 1 volt = 400 RPM
SCALE ABS. Time in Seconds
SPEED 1.3 fps(ms) 4.2 kts(fs)
CONFIG. Bare Hull

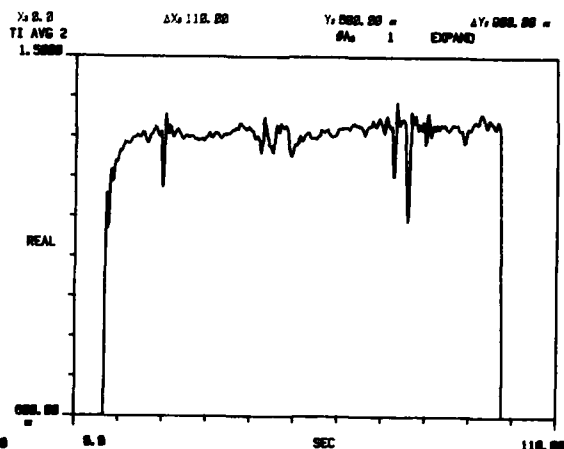
ΔXs 75.000
Ys 0.0
0As 1
EXPAND
ΔYs 000.00 =
Xs 0.0
TI AVG 2



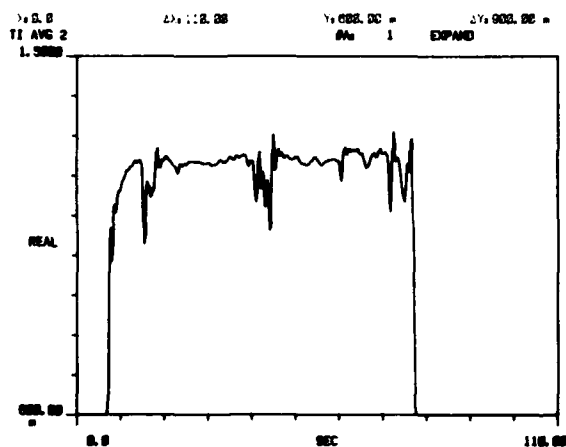
DATE 30 April 1979
RUN NO. 9 2
CHAN NO. 5 Speed
ICE TH. 3.06 in(ms) 61.2 in(fs)
SCALE ORD. 1 volt = 5 fps(ms) ~13 kts(fs)
SCALE ABS. Time in Seconds
SPEED 1.6 fps(ms) 4.2 kts(fs)
CONFIG. Bare Hull



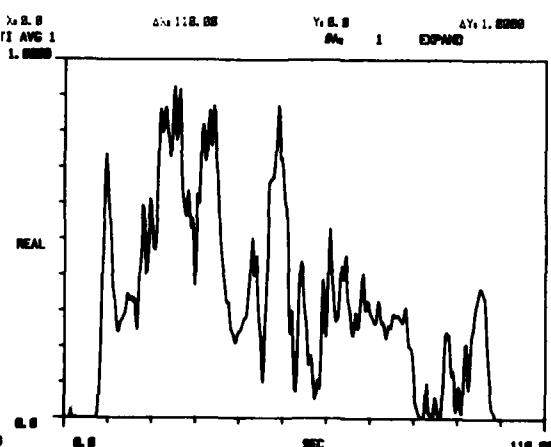
DATE 2 May 1979
 RUN NO. 10 1
 CHAN NO. 1 Port RPM
 ICE TH. 1.8 in(ms) 37.2 in(fs)
 SCALE ORD. 1 volt = 400 RPM
 SCALE ABS. Time in Seconds
 SPEED 1.8 fps(ms) 4.7 kts(fs)
 CONFIG. Fins



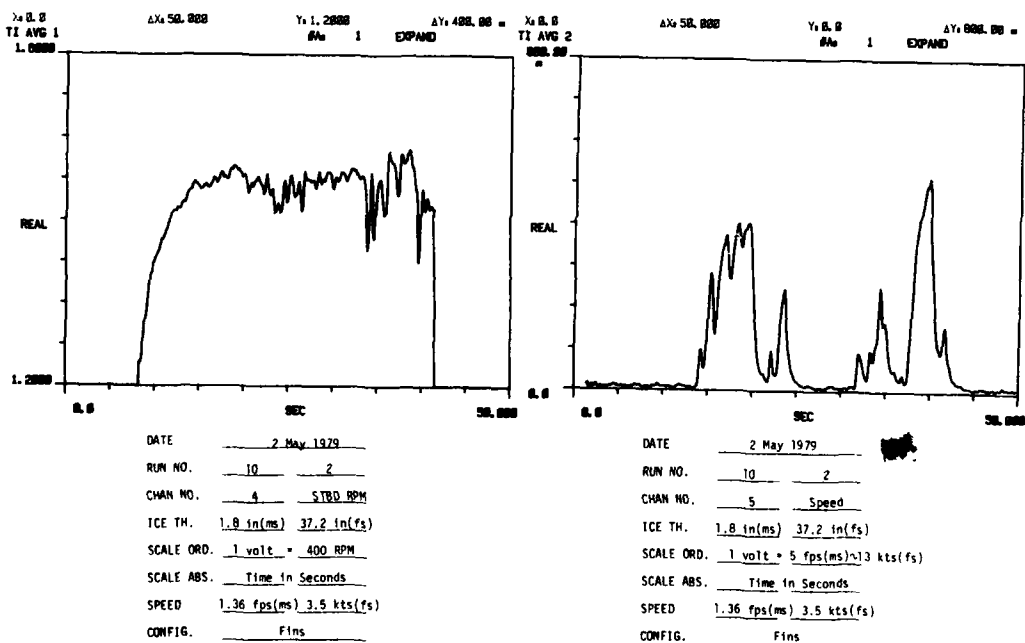
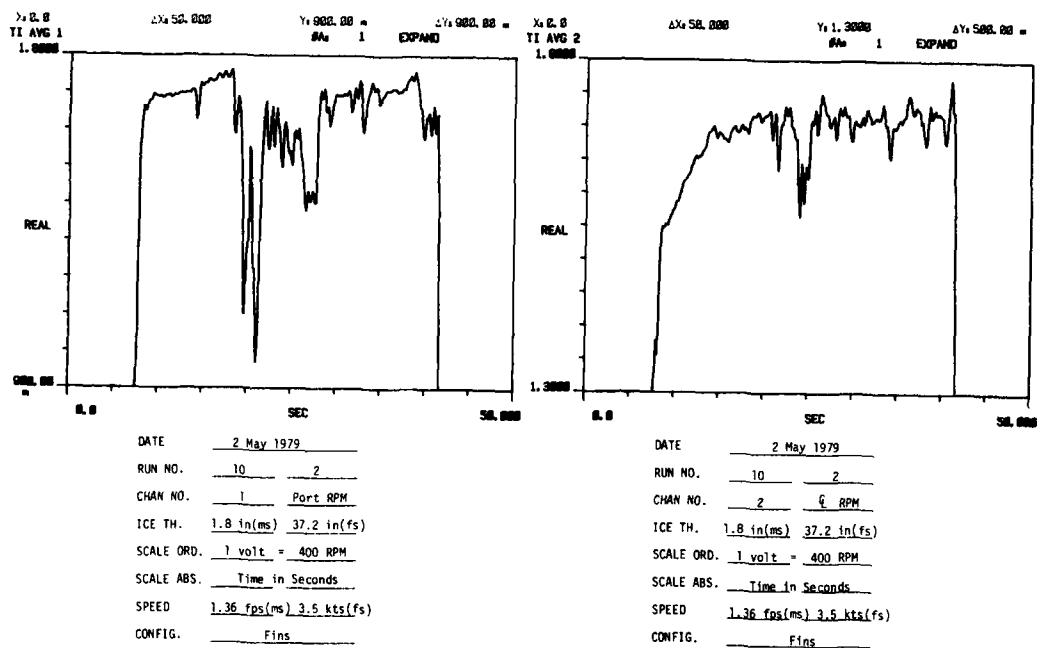
DATE 2 May 1979
 RUN NO. 10 1
 CHAN NO. 2 9 RPM
 ICE TH. 1.8 in(ms) 37.2 in(fs)
 SCALE ORD. 1 volt = 400 RPM
 SCALE ABS. Time in Seconds
 SPEED 1.8 fps(ms) 4.7 kts(fs)
 CONFIG. Fins

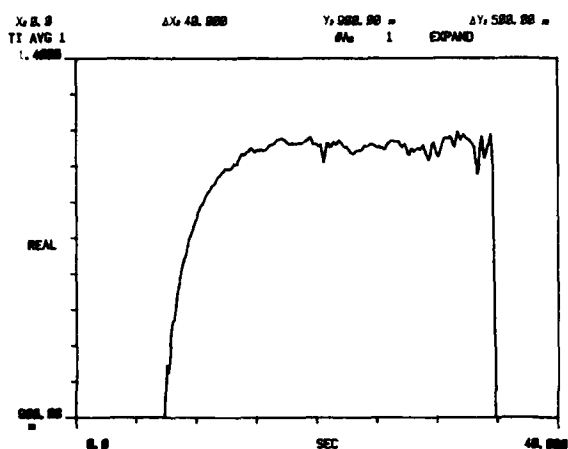


DATE 2 May 1979
 RUN NO. 10 1
 CHAN NO. 4 STBD RPM
 ICE TH. 1.8 in(ms) 37.2 in(fs)
 SCALE ORD. 1 volt = 400 RPM
 SCALE ABS. Time in Seconds
 SPEED 1.8 fps(ms) 4.7 kts(fs)
 CONFIG. Fins

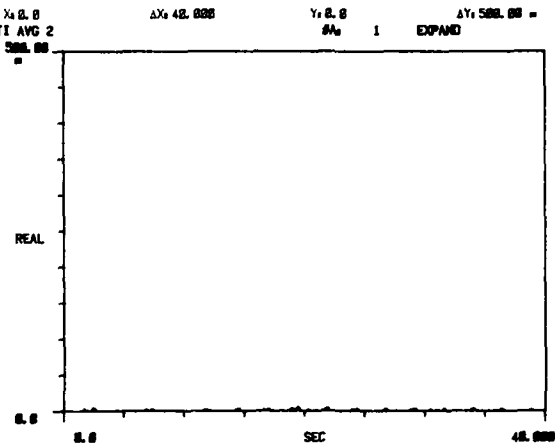


DATE 2 May 1979
 RUN NO. 10 1
 CHAN NO. 5 Speed
 ICE TH. 1.8 in(ms) 37.2 in(fs)
 SCALE ORD. 1 volt = 5 fps(ms) ~13 kts(fs)
 SCALE ABS. Time in Seconds
 SPEED 1.8 fps(ms) 4.7 kts(fs)
 CONFIG. Fins

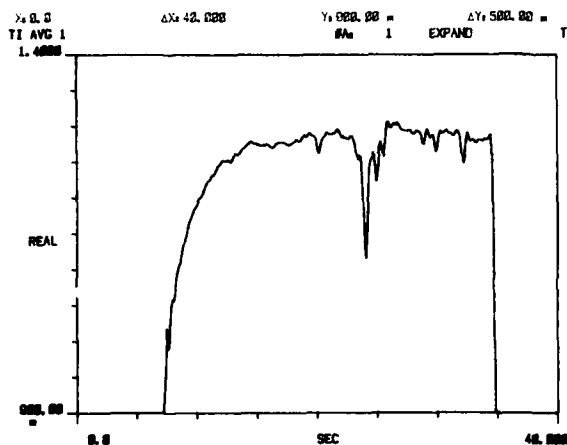




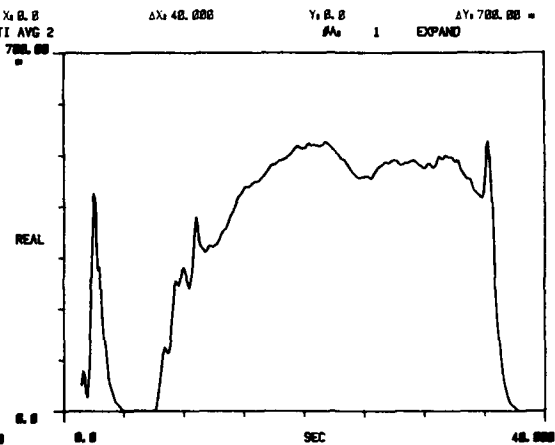
DATE 4 May 1979
 RUN NO. 11 1
 CHAN NO. 1 Port RPM
 ICE TH. 1.57 in(ms) 30.1 in(fs)
 SCALE ORD. 1 volt = 400 RPM
 SCALE ABS. Time in Seconds
 SPEED 1.82 fps(ms) 4.7 kts(fs)
 CONFIG. Small Bilge Keel



DATE 4 May 1979
 RUN NO. 11 1
 CHAN NO. 2 0 RPM
 ICE TH. 1.57 in(ms) 30.1 in(fs)
 SCALE ORD. 1 volt = 400 RPM
 SCALE ABS. Time in Seconds
 SPEED 1.82 fps(ms) 4.7 kts(fs)
 CONFIG. Small Bilge Keel



DATE 4 May 1979
 RUN NO. 11 1
 CHAN NO. 4 STBD RPM
 ICE TH. 1.57 in(ms) 30.1 in(fs)
 SCALE ORD. 1 volt = 400 RPM
 SCALE ABS. Time in Seconds
 SPEED 1.82 fps(ms) 4.7 kts(fs)
 CONFIG. Small Bilge Keel

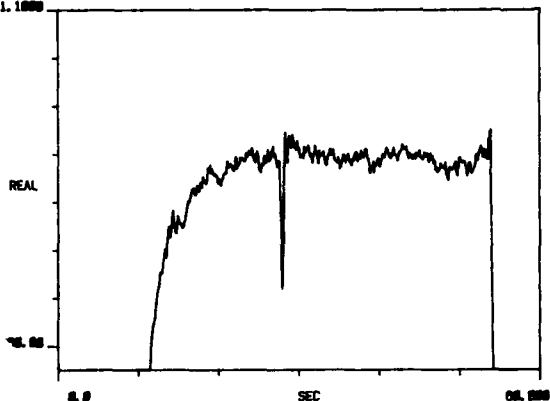


DATE 4 May 1979
 RUN NO. 11 1
 CHAN NO. 5 Speed
 ICE TH. 1.57 in(ms) 30.1 in(fs)
 SCALE ORD. 1 volt = 5 fps(ms) ~13 kts(fs)
 SCALE ABS. Time in Seconds
 SPEED 1.82 fps(ms) 4.7 kts(fs)
 CONFIG. Small Bilge Keel

Y: 0.0
TI AVG 2
1.1000

ΔX: 00.000
Y: 050.00 =
#A: 1 EXPAND

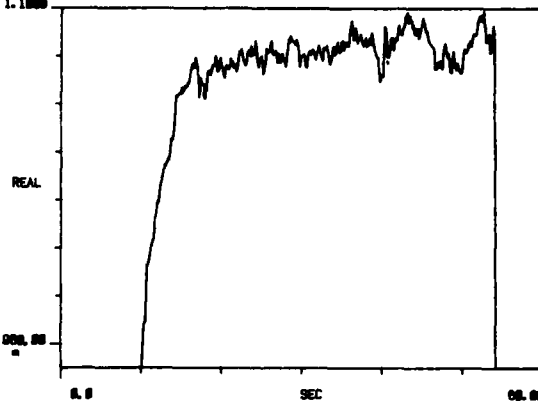
ΔY: 150.00 =
X: 0.0
TI AVG 1
1.1000



DATE 4 May 1979
RUN NO. 11 2
CHAN NO. 1 Port RPM
ICE TH. 1.57 in(ms) 30.1 in(fs)
SCALE ORD. 1 volt = 400 RPM
SCALE ABS. Time in Seconds
SPEED 1.5 fps(ms) 3.8 kts(fs)
CONFIG. Small Bilge Keel

ΔX: 00.000
Y: 050.00 =
#A: 1 EXPAND

ΔY: 150.00 =
X: 0.0
TI AVG 1
1.1000

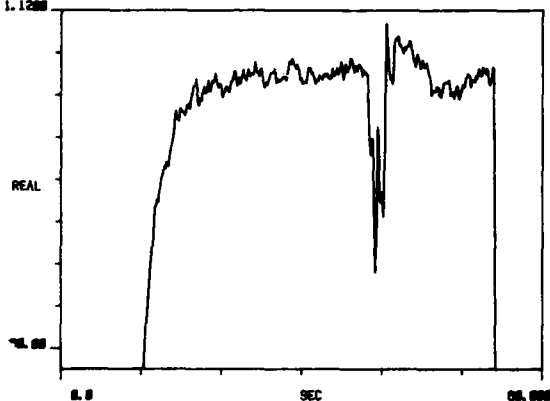


DATE 4 May 1979
RUN NO. 11 2
CHAN NO. 2 6 RPM
ICE TH. 1.57 in(ms) 30.1 in(fs)
SCALE ORD. 1 volt = 400 RPM
SCALE ABS. Time in Seconds
SPEED 1.5 fps(ms) 3.8 kts(fs)
CONFIG. Small Bilge Keel

Y: 0.0
TI AVG 1
1.1200

ΔX: 00.000
Y: 050.00 =
#A: 1 EXPAND

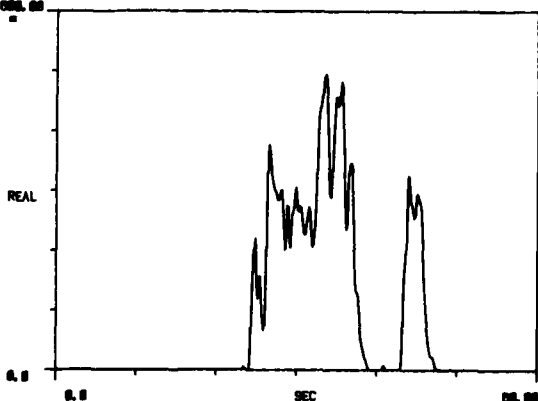
ΔY: 170.00 =
X: 0.0
TI AVG 2
000.00 =



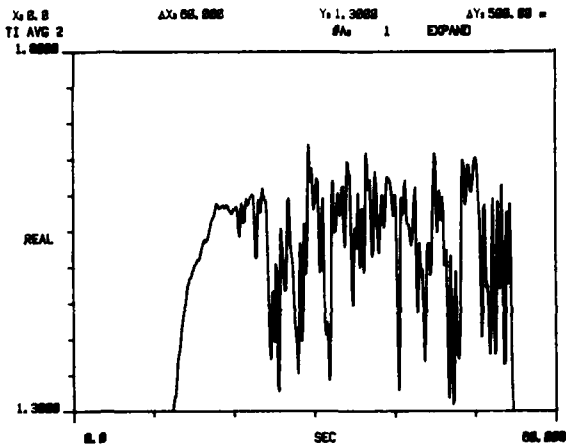
DATE 4 May 1979
RUN NO. 11 2
CHAN NO. 4 STBD RPM
ICE TH. 1.57 in(ms) 30.1 in(fs)
SCALE ORD. 1 volt = 400 RPM
SCALE ABS. Time in Seconds
SPEED 1.5 fps(ms) 3.8 kts(fs)
CONFIG. Small Bilge Keel

ΔX: 00.000
Y: 0.0 =
#A: 1 EXPAND

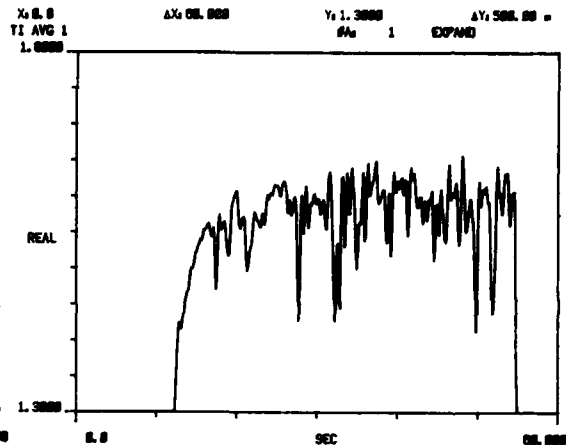
ΔY: 000.00 =
X: 0.0
TI AVG 2
000.00 =



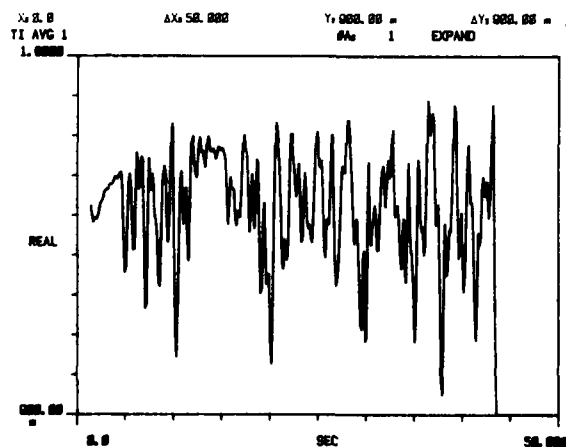
DATE 4 May 1979
RUN NO. 11 2
CHAN NO. 5 Speed
ICE TH. 1.57 in.(ms) 30.1 in(fs)
SCALE ORD. 1 volt = 5 fps(ms) ~13 kts(fs)
SCALE ABS. Time in Seconds
SPEED 1.5 fps(ms) 3.8 kts(fs)
CONFIG. Small Bilge Keel



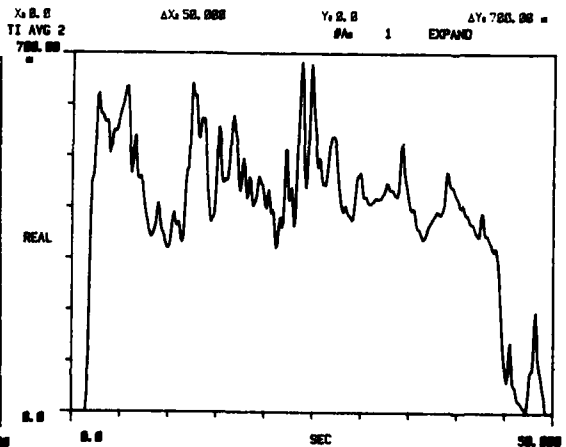
DATE 7 May 1979
 RUN NO. 12 1
 CHAN NO. 1 Port RPM
 ICE TH. 2.28 in(ms) 43.6 in(fs)
 SCALE ORD. 1 volt = 400 RPM
 SCALE ABS. Time in Seconds
 SPEED 1.63 fps(ms) 4.23 kts(fs)
 CONFIG. Bare Hull



DATE 7 May 1979
 RUN NO. 12 1
 CHAN NO. 2 Q RPM
 ICE TH. 2.28 in(ms) 43.6 in(fs)
 SCALE ORD. 1 volt = 400 RPM
 SCALE ABS. Time in Seconds
 SPEED 1.63 fps(ms) 4.25 kts(fs)
 CONFIG. Bare Hull



DATE 7 May 1979
 RUN NO. 12 1
 CHAN NO. 4 STBD RPM
 ICE TH. 2.28 in(ms) 43.6 in(fs)
 SCALE ORD. 1 volt = 400 RPM
 SCALE ABS. Time in Seconds
 SPEED 1.63 in(ms) 4.23 kts(fs)
 CONFIG. Bare Hull



DATE 7 May 1979
 RUN NO. 12 1
 CHAN NO. 5 Speed
 ICE TH. 2.28 in(ms) 43.6 in(fs)
 SCALE ORD. 1 volt = 5 fps(ms) ~13 kts(fs)
 SCALE ABS. Time in Seconds
 SPEED 1.63 fps(ms) 4.23 kts(fs)
 CONFIG. Bare Hull